SIMULATION OF AN OVERHEAD CRANE SYSTEM

By

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CERTIFICATE

This is to certify that the thesis entitled "SIMULATION OF AN OVERHEAD CRANE SYSTEM" by Dilip Bhargava is a record of work carried out under my supervision and has not been submitted elsewhere for a degree.

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In this study simulation models have been developed to study the utilization of cranes in an overhead crane system for one of the leading steelplants in India. This study is primarily restricted to the conditioning bay of Rail and Structural Mill of Bhilai Steel Plant. The following three policies have been studied with a view to increase the utilization of the cranes :

POLICY A - The whole length of the bay under study has been divided into two areas by means of a platform. Each crane is restricted to move in one of the areas of the bay. The rails waiting for their removal from the platform are assigned a higher priority as compared to the rails reaching the platform.

POLICY B - In this policy, both the cranes are allowed to travel in whole of the bay. Whenever a crane is blocked by the other crane, no transfer of material from one crane to the other is allowed. The cranes are allowed to move according to one of the following

rules at the time of intercrane interference :

(a) The loaded crane is allowed to move while the movement of the free crane is pre-empted.

(b) If both the cranes are loaded, the crane nearer to its destination is assigned a higher priority for movement.

POLICY C - In this policy also, both the cranes are allowed to move in whole length of the bay. Whenever a conflict occurs between two loaded cranes, the crane nearer to its destination is allowed to move whereas the other loaded crane's movement is pre-empted. If the interference occurs between a loaded crane and a free crane, a check is made to determine whether the pre-emption of the free crane is better or the unloading of the loaded crane and the loading of the free crane with the same load is better. Using the criterion of effective utilization of these cranes, one of these two alternatives is selected.

The effects of the speed of the cranes as well as the changes in the layout of the facilities have been studied with a view to limit the size of the queues formed at the cooling beds, the platform and the cooling pits.

GPSS III has been used as the programming language. A computer package has been written for IBM 7044 system. The proposed models have been analysed and to some extent validated using the data obtained from Bhilai Steel Plant.

CHAPTER I

INTRODUCTION

1.1 Materials Handling in Steel Industry

A characteristic feature of iron and steel making is the great bulk of raw materials used. On an average for every tonne of finished steel sent out, an integrated works takes in atleast 4 tonne of raw materials. Besides a considerable amount of in-process handling, there is an enormous amount of material transported into and out of the plant. Materials handling costs, probably, account for higher proportion of production costs in a steel plant than in any other industry. More than one-third of the capital investment in iron and steelmaking plant is for material handling equipments. Thus storage, handling and transport of materials can have an important influence on the economy of operations.

The inplant handling costs and external transportation costs vary from plant to plant. It depends on the scale of operations, layout of the production facilities and modes of transportation provided. In many cases the mode of external transportation e.g. road, rail, conveyor etc. is solely selected on the basis of economic considerations. In some instances the

choice is predetermined by factors such as proximity to sources of supply or markets, and existing communications.

1.2 Materials Handled in Steel Industry

The materials to be handled in an iron and steel industry may be classified into four main groups :

(i) Incoming materials (raw materials, fuels, repair materials etc.)

(ii) In-process transfer of materials

(iii) Finished products

(iv) Waste and byproducts

However, from the reception of raw materials to the despatch of finished products, on an average, atleast 10 tonne of materials had to be moved per tonne of finished steel. This figure is based on the single handling of the material. Many a times the same material has to be handled a number of times. Over and above that, for a bigger steel plant producing say 2.5 million tonne of steel per year, materials handling problems increase exponentially. A plant having still higher production target may be handling and transporting well over 1 million tonne of materials per week. The transport and handling of material for an iron and steel plant is obviously a tremendous undertaking. The ability to handle materials within the plant itself

could ultimately become the principal factor which limits the production.

Handling methods or policies undoubtedly offer considerable scope for improving the overall economy of operations. Even small savings per tonne of material handled may well be worthwhile when magnified by vast quantities of raw materials and innumerable products which have to be handled.

1.2.1 Incoming and outgoing materials

The methods of shipping raw materials to the plant and of taking away the finished products influence the pattern and economics of internal transport. Once roadways or a railway system has been introduced, it becomes increasingly attractive to use it more extensively to its limit. It is appropriate, therefore, to consider briefly the materials movement to and from the plant before examining the case of handling within the works.

The tonnage of raw materials to be handled is obviously far greater than that of the finished products. This regular high density traffic between the fixed terminals offers considerable scope for elaboration and refinement of loading and unloading arrangements. Except where works are located within conveyor reach of a deep water-port or mine, raw materials are traditionally delivered by rail. However, there are some instances of materials, such as lime stone and dolomite which are

required in relatively small quantities, being delivered by road vehicles.

Finished products are generally consigned in smaller quantities to numerous destinations. This calls for greater flexibility in handling. Provision exists for both road and rail deliveries from the despatch areas of all the production departments of a steel plant. Economically advantageous form of transportation can be selected where a choice exists. In most of the cases, this choice is probably dictated more by customers' preference and by the physical dimensions of the product than by economic considerations. For example, the customers near the steel works or without railway sidings prefer deliveries of finished products by road transport.

1.2.2 Internal transport and handling

(a) Iron and Steelmaking raw materials :

The major handling problem is the bulk handling of raw materials to the blast furnace. Iron ore, coal etc. are brought to the works by rail. Subsequent distribution within the works is achieved by conveyors. Conveyor is advantageous for the large tonnage of bulk materials at steady rates over relatively short distances. In a steel plant the use of travelling boom-stackers and bucket wheel reclaimers are means of stacking and reclaiming ironmaking raw materials. Elevators or skip-cars are widely used for feeding the materials to

the furnace bunkers.

(b) Hot Metal :

Hot metal from the blast furnace is traditionally transported in ladles on standard-guage rail carriages. It involves regular duties for the internal works locomotives.

(c) Scrap :

Scrap is collected and transported in rail vehicles of robust construction to scrapyard.

(d) Ingots :

Methods of handling ingots from the casting bay to the soaking pits are governed to a great extent by thermal considerations. After being cast, an ingot must be left in its mould for a period to freeze before being stripped. After stripping, the ingot needs to be placed in the soaking pits as soon as possible to conserve heat. The train loads of ingots are hauled in their moulds to the mill and stripped near the soaking pits.

(e) Slag and Rubbish :

Slag is usually regarded a by-product instead of a waste material. Metal recovery is also profitable and is the reason for processing steelworks slag. The slag handling involves not only the removal from the furnace but also subsequent processing to turn it into a saleable

product. Either road or rail transport is used for removal of steelworks slag.

Rubbish consists mainly of the debris from furnace demolition and the steel plant casting operations. This is usually dumped manually or by grab cranes or by means of a mobile tippler after recovery of metal and usable refractory bricks.

(f) Semifinished rolled products :

The intermediate transfer of semifinished rolled products between primary and secondary mills is effected mainly by rail transport.

1.3 Handling Within A Department

The various examples of transport of materials so far dealt with have all been concerned with inter-departmental movements. Within each department, however, there takes place a considerable amount of movement of materials being processed. Such handling is more closely associated with the process itself than is inter-departmental transport. Accordingly, process needs have a greater influence on the means of handling adopted within a department.

Indeed, the handling costs themselves may have little or no influence on the choice of that handling method which may be determined solely by its effect on the process costs. Secondly, the layout may have a greater

influence on the choice of equipment than the handling costs.

Because of this close association between handling, process and layout when considering movements within a department, it is considered that no useful generalization can be formulated by considering handling costs in isolation.

Keeping in view the enormous material handling in an iron- and steelmaking plant, the present study has been undertaken to evaluate the possibilities of introducing rational approaches for material handling problems. This study is conducted for Bhilai Steel Plant which is one of the leading steel plants in India producing over 2.5 million tonne of steel ingots per year. It is estimated that more than 60,000 tonne of material is handled daily in this plant.

The large tonnage items such as iron ore, coal etc. are usually delivered by scheduled trains. Self-discharging dump trucks of 15 to 30 tonne load carrying capacity are used for transporting dolomite, lime stone etc. 5 tonner four-wheeled fixed platform to 15 tonner eight-wheeled fixed platform or trailer type road vehicles are used to deliver finished products. The transport of fluids such as oil and gas by pipeline is a well established practice.

The inter-departmental flow of materials in Bhilai Steel Plant is shown in Fig. 1. The blocks represent the various departments and the arrows show the movement of material between the departments. There are three production departments, viz. Wire Rod Mill, Merchant Mill and Rail and Structural Mill. Besides the products of these production departments, a fraction of Billet Mill products is also sold in the market.

As mentioned earlier, materials handling within a department itself is quite considerable. Side loaders are used exclusively for billet handling in the billet inspection and dressing shops of Bhilai Steel Plant. Straddle carriers are particularly useful for slab handling in outer-stockyards. Transfer rope skids are used for bay to bay movements. Mobile equipment provides greater flexibility in movements but the overhead crane does offer, however, some advantages in being able to lift and carry loads over obstructions.

Facilities are provided for both road and rail deliveries from the despatch areas of all the production shops of Bhilai Steel Plant. Overhead cranes are most commonly used for loading the road or rail transport facility. As alternatives, fork trucks, side loaders and straddle carriers offer advantages of mobility but require more space to manoeuvre. Overhead cranes working in conjunction with mobile equipment may be advantageous

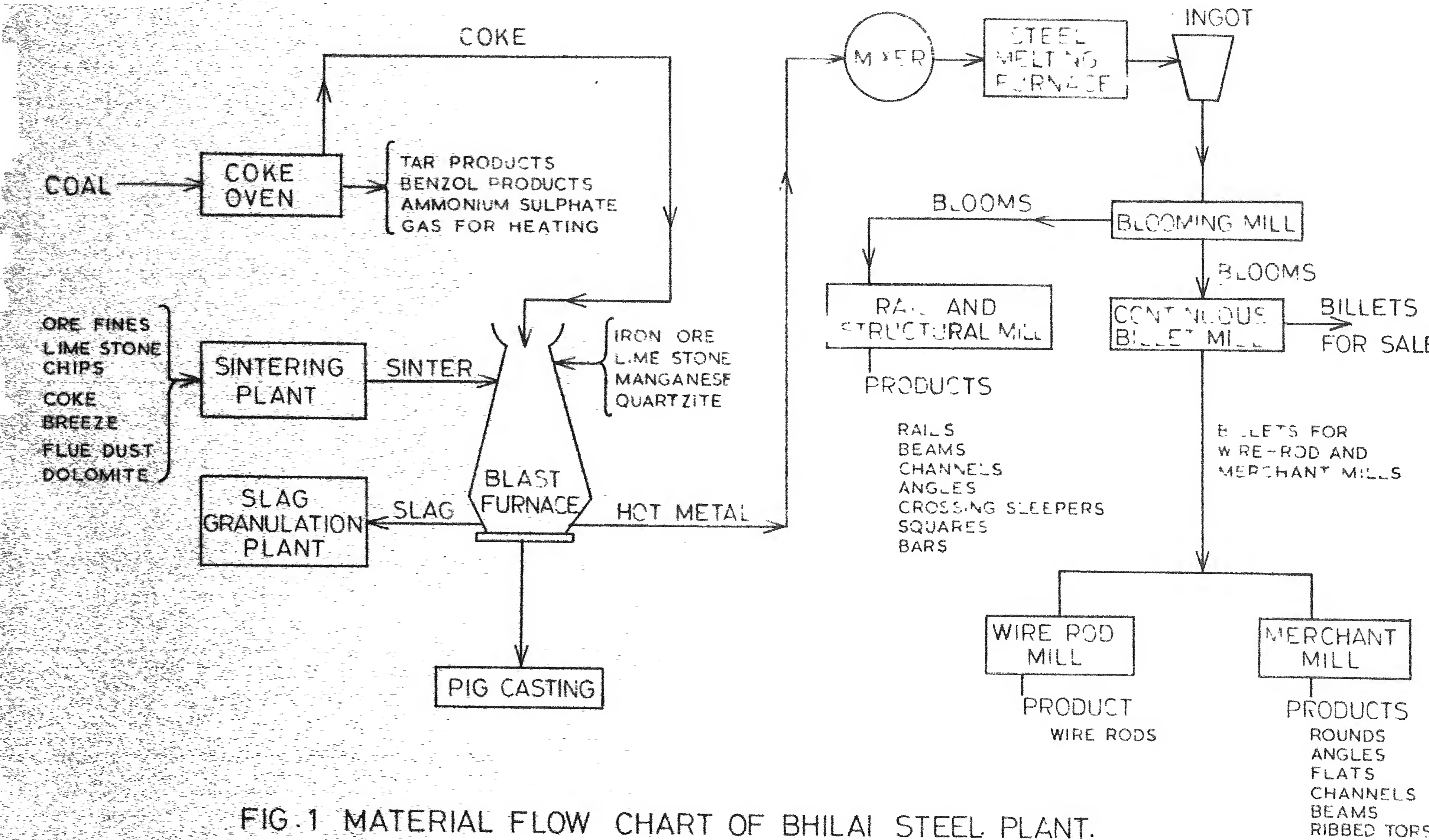


FIG. 1 MATERIAL FLOW CHART OF BHILAI STEEL PLANT.

realistic model of the overhead crane system, the process and the system behaviour have been studied critically. Certain assumptions (discussed in Section 3.1) have been introduced to help in the structuring of the simulation model. The development of the simulation models and the design of simulation runs is dealt with in Chapter III.

The system is analysed and the results are reported in Chapter IV. The discussion on the results obtained is also given in the same Chapter. A few comments on the acceptance and implementation of the results, the possibility for the complete automization of the rails-handling system and the scope for further research are given in Chapter V.

CHAPTER II

STUDY OF THE SYSTEM UNDER INVESTIGATION

2.1 Introduction

According to fourth Five Year Plan, out of the target total production of 14.8 million tonne of ingot steel per year, Bhilai Steel Plant will contribute production of 3.2 million tonne of ingot steel per year. At present Bhilai Steel Plant produces 2.5 million tonne of ingot steel per year. Steel balance chart for Bhilai Steel Plant is shown in Fig. 2.

The Rail and Structural Mill of Bhilai Steel Plant (Fig.3) is designed to produce 0.75 million tonne of finished steel products per year. A fraction of ingots rolled in Rolling Mills is transferred to Rail and Structural Mill in the form of blooms. To avoid flocks, all the rail blooms are charged into the heating furnaces (continuous type double row, end discharge - 3 in number). These rail blooms when hot are rolled first through one roughing stand (2-high reversible type), then through two finishing stand (3-high) in number of passes and finally through 2-high finishing stand in a single pass. Completely rolled rails are then cut while hot by circular disc saws into pieces of desired length and each length is marked by stamping machine.

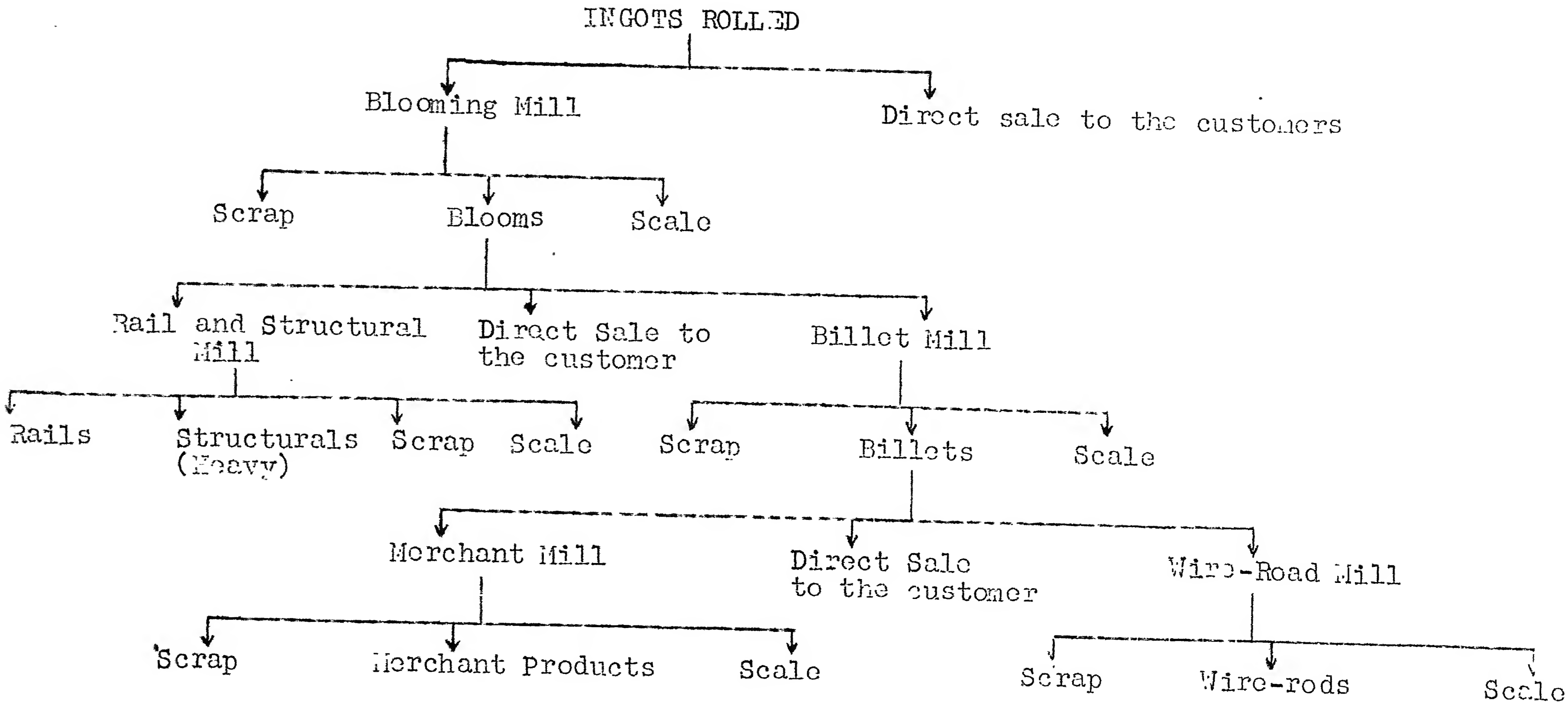


Figure 2. Steel Balance Chart for Bhilai Steel Plant

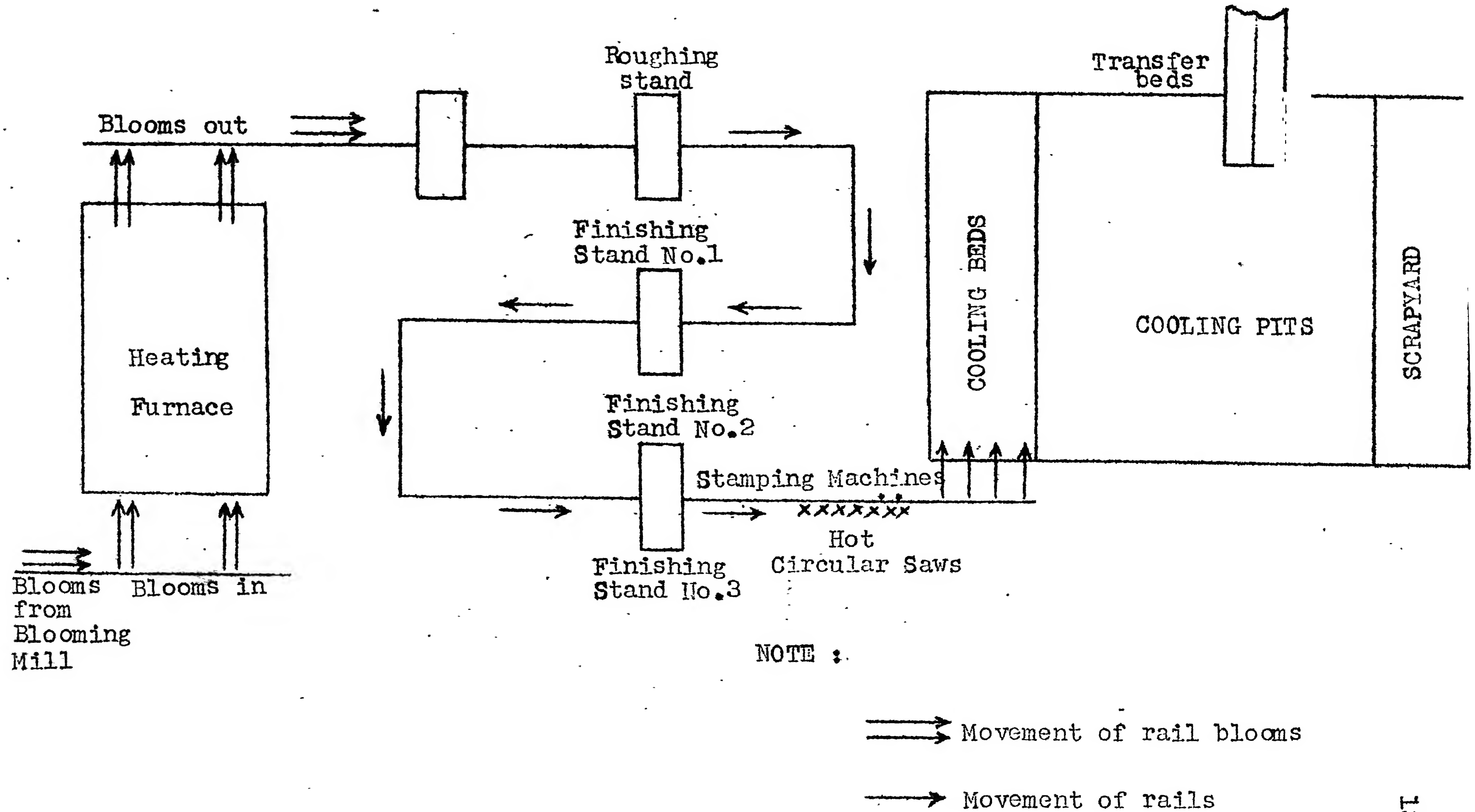


Figure 3 : Flow of Material inside Rail and Structural Mill (B.C bay only)

After cutting and marking, the rails are conveyed on roll table to cooling beds. From here the rails made of 'open hearth furnace' steel, once again to prevent formation of flocks, are taken to unheated pits by cranes where they are subjected to slow cooling for about 7 to 8 hours. The slowly cooled rails are removed from pits by means of cranes and are placed either on a bed from where they are transferred one by one to the roller type straightener or to the scrapyard where from they are sold in open market. This choice of destination depends on the test reports from the mechanical and metallurgical laboratories. After straightening, the rails are sent for finishing and inspection. The good rails are then transferred to warehouses or loaded on flat-cars; others are sent for further conditioning.

2.2 System Under Investigation

This section describes the overhead cranes system in the B-C bay (conditioning section) of Rail and Structural Mill to be studied.

A pair of overhead cranes equipped with rigid guides and special high temperature electromagnets are required to span the whole area of B-C bay under study. This portion of the bay is 350 metres in length and 30 metres across. The following are the specifications for the cranes used in this bay :

Average linear speed of the cranes bridge =155 metres/minutes
Average cross speed of the cranes cab = 61 metres/minutes
Upward/downward speed of the cranes hook = 15 metres/minutes
Lifting capacity of the cranes hoisting gear = 35.4 tonne
Height of craneways above the level of ground = 6.0 metres
Useful lifting capacity of the cranes = 15 tonne
Span of the cranes bridge = 28 metres
Length of the cab travel on the bridge = 24 metres

The rails, after being cut and marked while hot, are conveyed on roll tables to the fourth cooling bed and subsequently to third, second and first cooling beds. At the cooling beds the rails are turned over to get them with their base down and bundled. Each bundle comprises of 10 rails. The rails which are cooled to a temperature of about 550°C are taken in bundles by overhead cranes to the nearest available slow cooling pit.

There are 44 cooling pits each having a capacity for 120 rails. Each cooling pit can accommodate rails which are equal to or less than 13 metres in length. The bundles (10 rails in a row) are separated by three 40 x 40 mm - square section carbon steel bars placed at a distance of 2 to 4 metres from the ends of the rail. The slow cooling pits offer a reliable

method of preventing flocks in the rails and they simultaneously serve as an intermediate storage space before the finishing line.

The temperature of the rails taken from the cooling beds and charged into the cooling pits should not be less than 550°C for the first three bundles and should not be less than 500°C for the rest. Further, the temperature of the lower row at the time of covering the pit should not be less than 350°C.

The rails are kept in the pits with tightly closed covers under prescribed temperature conditions for 7 to 7½ hours and are discharged 1/2 to 1 hour after the cover is opened. The placing of covers on the pits and their removal is done by overhead cranes.

The test report from mechanical and metallurgical laboratories decides the destination of the rails which have been cooled in the pits. If the report is favourable, the rails are taken by cranes to the transfer-beds. From here the rails are fed one by one to roller type straightener which straightens the rails along the plane perpendicular to the base. The straightening speed is 1.0 to 1.6 metres per second. If the test report is not favourable, the rails are transferred by means of the cranes to scrapyard from where they are sold in open market.

One cab of 4 metres x 4 metres size is available for use on each overhead crane, therefore, the hook of the cranes can traverse 28-4=24 metres of space across the bay. The bridges of both the cranes mounted on the same tracks can travel in an East-West direction. The movement of the crane is controlled by an operator who sits in the cab. The cab can traverse on the bridge in the North-South direction.

The mill runs for 3 shifts i.e. 24 hours a day but the hot hour production is for 13 to 19 hours a day whereas the cranes are in operation for 6 to 7 hours during a shift of 8 hours.

2.3 Problem Formulation

In the past the labourers in the Rail and Structural Mill have been requesting the management that in order to cope up with the production requirement of the rails, it is necessary to have a third crane in the conditioning section of the B-C bay of the mill. However, the management thinks that the two cranes presently installed in this bay are not being utilized to their fullest extent. Therefore, the introduction of the third crane is an inappropriate proposition. This led the author to believe that there is a necessity to conduct a scientific study on the crane system so as to justify or contradict the view-points putforth by the management.

The problem can be stated as "to study the utilization of the overhead cranes in the existing system and to examine if the utilization of the cranes can be improved upon by adopting a different policy for using the cranes or by changing the layout of the facilities in the bay".

2.4 Review of Earlier Work

The basic concepts of designing a material handling system have been considerably changed in the last three decades. Previously the design of the materials handling system was done mainly based on the experiences of individual engineers. However, with the development of sophisticated tools of Operations Research, Computer Technology and Digital Simulation, the experience of individuals has been replaced by scientific and rational procedures for solving complex problems of materials handling.

A thorough survey of the literature indicates that no analytical approach has been so far proposed for designing the overhead crane system. This can be attributed to the nontractability of the complexities of such a system through analytical tools. However, in the literature, a few approaches have been suggested.

In 1965 Roy and Taha [6] simulated the operation of an overhead crane system. They assumed the flow of material to be in one direction. A machine

is assumed to have a new load always present in its adjacent in-process area. In their model, the crane which starts moving first is allowed to move till it reaches its destination and the other crane cannot enter the area between the former crane's starting position and destination till the former completes its movement. The objective of this study was to find the effect of location of machines and of crane's speed on the idle time per machine.

In 1971 Khan M. Usman [3] made an attempt to simulate the overhead crane system of 747 plant of Boeing Company. He has discussed the problem of 8 cranes working in 3 parallel bays and also in the connecting bays. In his model, the area of movement of each crane has been restricted to a particular grid area. Various rules have been discussed for assigning priorities when conflicts occur. He considered the path to be followed by a particular move to be fixed.

However, no work seems to have been reported in the literature for materials handling situations when the flow of material is taken to be in both the directions of movement of cranes. Therefore, in the present work, policies of using cranes having intercrane interference and a policy avoiding conflicts have been modelled and simulated for the overhead crane system.

2.5 Methodology Selection

Before selecting the methodology, the reader is introduced to the complexity of the system. The cranes in the conditioning section of the B-C bay of the Rail and Structural Mill are used only for handling rails. The conflicts are introduced when two or more cranes operate on the same track. For example, one crane is travelling from East to West, the crane in West end will be trapped until the former crane completes its operation and moves Eastward. The situation requires checking of existing move, the origin and the destination of the cranes movement and the occurrence of conflicts to reassign the destinations of the cranes moves. Such a type of operation represents a complex queueing situation for which a pure analytic solution is not possible. One of the most powerful means of handling complex problems which cannot be solved analytically, is through the use of 'Digital Simulation'.

While studying the system at Bhilai, the author felt that a total system simulation approach will assist in evaluating the mill resources. Also it would be helpful in forecasting problem areas which might arise due to a future requirement for an increase in the production or due to the changes in the rolling programmes of the mill. Therefore, in the present study digital simulation has been selected as the tool for the analysis

and design of the overhead cranes system.

2.6 Programming Language

Having decided 'Digital Simulation' as the tool for analysing the system, this section describes the reasons for using a special purpose simulation language rather than the more popular computer languages like FORTRAN and ALGOL. A few special facilities are commonly needed by a simulation programmer. The facilities are provided by the special purpose simulation languages but are not provided by the high level languages such as FORTRAN and ALGOL. The special programming facilities needed for simulation studies are listed below :

(i) Automatic time advance

The simulation approach, of course, is to work out all the movements in time sequence and record the occurrences of the actual states of the model system as the run progresses. All the entities of a model have to be moved together so that the interactions can be correctly represented. This poses a problem because of the sequential nature of computer calculations. A clock has to be set up recording the model time, and all necessary movements simulated. The clock can be advanced from event moment to event moment without halting at intervening times when no activity can

occur, since future events can be pre-timed.

A computer programming language designed specially for simulation work is provided with a built in CLOCK. It is clearly an advantage if a facility has been provided to advance time automatically, once all the relevant events have been processed.

(ii) Facilities for specifying decision rules

Complex decision rules form an essential part of most of the models. A decision rule can be expressed as a rule of choice among a set of alternatives. It is convenient, therefore, to have some type of list structure available and they are available in simulation languages.

(iii) Random sampling facilities

Nearly all simulation models involve taking random samples from specified probability distributions. Therefore, the simulation language should have a pseudo-random number generator. Also it is useful to have facilities for inputting a histogram and sampling from it, to enable empirical data on random fluctuations to be used where theoretical distributions are inappropriate.

(iv) Facilities for analysing results of runs and producing reports

The results of the simulation runs are normally required in the form of statistical summaries of the

mean values and variations of model variables. It is useful, therefore, to have a means of easily specifying the variables to be recorded, the distributions required (what intervals etc.), along with the layout of the results as finally printed.

Such facilities can reduce the programming effort enormously. Two main approaches have been adopted to the problem of providing these above-mentioned extra facilities. (a) The programme package approach, which consists of providing a set of useful programme routines which can be called on by the simulation programmer. The package can be written in one of the standard programming languages. The disadvantage with the package approach is that the facilities provided are somewhat limited. (b) The language compiler approach, which consists of creating a special simulation programming language. The compiler approach provides a fuller range of these superior facilities mentioned above as (i) through (iv). This approach suffers from the defect that it can only be used on those machines which have the appropriate compiler. Another point to bear in mind is that a period of several months is needed to gain full proficiency in a new programming language of this type.

Considering pros and cons of using a particular language for the simulation of overhead crane system under

study, the language compiler approach has been finally decided to work with. At I.I.T. Kanpur Computer Center, GPSS III which is a simulation language compiler is available on the IBM 7044 and therefore, GPSS III has been selected as the simulation language for this study.

2.7 System Synthesis

This involves determination of alternative solutions which will satisfy the stated objectives. The following are the alternative policies for the usage of cranes.

2.7.1 Policy A : In this policy the whole length of the bay B-C is assumed to be divided into two areas by means of a platform. To avoid inter-crane interference completely, each crane is restricted to move in one area of the bay. Hence if the rails are to be transferred from a place in crane 1 area to a destination in crane 2 area; the crane 1 will take the rails upto the platform and drop the rails there, then the crane 2 will come to the platform, pick up the rails and deliver them to their destination. The rails waiting at platform are given higher priority for their removal. Various positions of the platform with different positions of the transfer-bed have been tested using the same model.

2.7.2 Policy B : A more general policy will be the one in which both the cranes are allowed to travel in whole of the bay and whenever a crane is blocked by the other crane, the cranes are allowed to move according to the priorities assigned to them. In this work, for this policy the priorities are assigned to the blocked cranes according to the following rules :

(a) The loaded crane is assigned a higher priority than a free crane.

(b) If both the cranes are loaded at the time of conflict, the crane nearer to its destination is assigned a higher priority.

Thus the crane, to which a higher priority has been assigned, is allowed to move past the other crane's position whose use has been pre-empted. Various alternative locations of the transfer-bed are evaluated to determine its best location with a view to have higher utilization of the cranes and at the same time limit the queue contents below a permissible upper limit.

2.7.3 Policy C : This policy is more or less a combination of the above two policies. The norms of this policy state that whenever a conflict is introduced, test whether both the cranes are loaded or only one is loaded. If both the cranes are loaded at the time of a conflict, the priorities to the cranes are assigned

according to rule (b) of policy B. If only one crane is loaded at the time of the conflict, the following information is generated :

(i) The time that will elapse during movement of the loaded crane from its present position to its destination and back is computed (say t_1)

(ii) The time required for unloading the loaded crane and then loading the free crane is calculated (say t_2)

(iii) t_1 is now compared with t_2. If t_1 is less than t_2, the free crane's movement is pre-empted and the loaded crane is allowed to move past the position of conflict. Otherwise the loaded crane drops the rails on ground and free crane picks up the rails. The destinations are interchanged as the transfer of load takes place.

All the above three policies have been modelled for the existing layout. The necessary data have been collected/obtained from the Rail and Structural Mill of Bhilai Steel Plant. A number of experiments have been performed on these models changing the design variables such as shifting the location of transfer-beds, changing the speed of the cranes.

CHAPTER III

SIMULATION MODELS OF THE SYSTEM

3.1 Assumptions

The following assumptions are made to model the overhead crane system under investigation :

(i) All the units of Rail and Structural Mill are assumed to be continuously active round the clock. No allowance is made for shift changes, failures or any other interruptions in the system. However, due to mechanical, electrical and gas delays, the hot-hour production of rails is assumed to be between 5 to 7 hours during each shift of 8 hours.

(ii) The crane maintenance time is not considered due to the non-availability of complete data. It is assumed that the whole system is dead if both the cranes break down. This is because no new event occurs in the system after the cranes have broken down.

(iii) The crane operators are assumed to have full information about the status of pits. They know which one of the pits is ready to be discharged and the order in which the pits will become available for discharging.

(iv) It is assumed for this analysis that the free cranes remain at the positions where they complete their last service.

(v) It is assumed that the cranes start from and stop at middle of the storage pits, cooling beds etc. The time taken for crane movement is the maximum of the bridge movement time and the time taken by cab to adjust itself to the correct position. This is based on the fact that there will be (if needed) simultaneous movement of the cab and the bridge to attain their exact destination.

(vi) For the purpose of this simulation, the loading and unloading time for cranes are assumed to be uniformly distributed.

(vii) The cooling time required at cooling beds is assumed to have a normal distribution.

(viii) The time required by rails for cooling inside the closed cooling pits is assumed to be uniformly distributed between $6\frac{1}{2}$ to $7\frac{1}{2}$ hours.

(ix) The methods of assigning the cranes to calling rails and the assignment of priorities to moves at the time of conflict depend on the policy of using the cranes.

(x) A cooling pit cannot have more than 120 rails. No overcharging of pits is allowed.

(xi) The inter-arrival time of rails in the system is assumed to follow a uniform distribution.

(xii) The system under study is assumed to be independent of its environment. That is to say, enough rail blooms are available to be fed into the rails and structural mill. The finishing section of the mill is capable enough of clearing the rails off the transfer-beds well in time.

3.2 GPSS Models Development

To help the reader in understanding the models which are presented later in this section, a few definitions and symbols used in the models development are in order.

3.2.1 Nomenclature

Following is a list of GPSS entities and their interpretations as used in the development of the models for the overhead crane system.

(i) TRANSACTION - a unit of traffic in GPSS model. In this model, this represents a bundle of 10 rails. A few control transactions have also been used which are either dummy or represent mill control circuit.

(ii) FACILITY - an entity capable of servicing one transaction (10 rails) at a time.

Facility 1 = Crane 1 on the cooling beds side.

Facility 2 = Crane 2 on the scrapyard side.

Facility 11 = Fictitious facility introduced to collect the statistics of pre-emption of crane 1.

Facility 12 = Fictitious facility introduced to collect the statistics of pre-emption of crane 2.

(iii) STORAGE - an entity which has multiple capacity i.e. it can process more than one transaction at a time.

Storage 1,2,3 and 4 = Cooling beds 1,2,3 and 4 respectively.

Storage 11 through 54 = Cooling pits 1 through 44.

Storage 55 through 90 = Scrapyard sections 1 through 36.

(iv) LOGIC SWITCH - an entity capable of residing in either of two states, SET or RESET.

Logic Switch Number	SET	RESET
100	Rolling of rails is switched off.	Rolling of rails is going on.
90	Hot-hour rolling of rails is going on during a shift.	Hot-hour rolling is off for some time during a shift.
111	Crane 1 hook is loaded.	Crane 1 hook is free.
211	Crane 2 hook is loaded.	Crane 2 hook is free.

(v) SAVEVALUE - a variable denoted by Xn or indirectly addressed as X*n.

X1,X2,X3,X4 = Distances of centres of cooling beds 1,2,3 and 4 respectively, from the left edge of Ist cooling bed which is taken as the origin.

X5 = 25200 seconds; mean service time in the cooling pits.

X6 = FN2 value; number of hot-hour minutes during an 8-hour shift.

X7 = Count for bundles of rails reaching the cooling bed.

X8 = Count for moves starting from rails leaving the queue at beds.

X9 = Location of centre of transfer-bed 1.

X10 = Location of centre of transfer-bed 2.

X11 through X54 = Positions of pits' centres where cranes stop to serve them.

X55 through X90 = Positions of rejected rails stacks in scrapyard.

X91 = Initial position of crane 1.

X92 = Initial position of crane 2.

X100 = Life of rail rolls; time upto which rolling of rails is done in one rolling programme.

X101 = One rolling programme; time upto which rolling of rails is off after X100 seconds.

X111 = Present position of crane 1 at any instant.

X112 = Destination of crane 1 at any clock time.

X113 = Direction of movement of the bridge of crane 1 (X113 can be +1, -1 or 0)

+1 means that crane 1 is moving from West to East

-1 means that crane 1 is moving from East to West

0 means that crane 1 is at rest.

X115 = Average linear speed of crane 1.

X125 = Mean cooling time at cooling beds.

X151 = -1, a constant.

X155 = Count of pits whose rails have been rejected.

X200 = Clock time at which production of rails is switched off.

X201 = Clock time in seconds at which production of rails is restarted.

X211 = Present position of crane 2.

X212 = Destination of crane 2.

X213 = Direction of movement of bridge of crane 2 (X213 can be +1,-1 or 0).

+1 means that crane 2 is moving from West to East.

-1 means that crane 2 is moving from East to West.

0 means that crane 2 is at rest.

X215 = Average linear speed of crane 2.

X300 = Generation time in hours after which the test report is received at the cooling pits.

(vi) QUEUE - A group of transactions waiting for a facility.

QUEUE 1 = Rails waiting at roll table for space at cooling beds.

QUEUE 2 = Rails waiting at cooling beds for the availability of cranes.

QUEUE 3 = Rails waiting at platform for the cranes (applicable to policy A only)

QUEUE 5 = Rails after cooling in the pits waiting for cranes availability.

(vii) PARAMETER - One of the twelve variables associated with a transaction.

P1 = An indicator to show which crane is to be pre-empted.

P4 = Identification of the cooling bed number on which rails lie.

P6 = Identification of cooling pit number in which rails rest for 7 to 8 hours.

P7 = Identification of the section number in scrapyard.

P8 = Highest numbered pit in the column of pits by the side of which platform is assumed to be existing.

P9 = Used to transfer the GPSS control using parameter selection mode.

P10 =
- 0 means that the rails are rejected from Crane 1 area.
- 1 means that the accepted rails lie in crane 1 area.
- 2 means that the accepted rails lie in crane 2 area.
- 3 means that the rejected rails belong to crane 2 area.

P12 = 100 means that the rails belong to crane 1 region.

P12 = 200 means that the rails belong to crane 2 region.

(viii) FUNCTION - permits the computation of continuous or discrete functional relations between an independent variable and the dependent values of the function.

(a) FN1 defines one rolling programme in hours. One rolling programme is the time between two consecutive starts of rolling compaigns for the rails. This function has been defined

on the basis of data collected over the past 5 years.

(b) FN2 gives in minutes the time for which hot-hour production goes on in a shift of 8-hours.

(c) FN3 evaluates the life of rail rolls which in turn decides the time for which the rolling of rails is to be done in one programme.

(d) FN10 gives normally distributed pseudo-random numbers.

(ix) ARITHMETIC VARIABLES - an arithmetic expression. A number of variable definition cards have been inputted to calculate the movement time of the cranes from one place to other and to compute service time at various beds, pits.

3.2.2 GPSS Models

Although the models have been developed with special reference to the operations of overhead cranes at Rail and Structural Mill of Bhilai Steel Plant, the analysis is applicable to all steel production systems of the same type. For this simulation study, one second has been selected as the minimum time increment. Any event/s which in the real world might occur within a fraction of a second are truncated to the nearest integer in the model.

Since nearly 400 GPSS blocks have been used to construct the various phases of the model, only the important features instead of detailed description are given in following paragraphs. Necessary comments have been put along with the GPSS blocks for better understanding of the programme.

The first block in GPSS programme is a GENERATE block. This block is used to create transactions i.e. the creation of batches of rails. The created transactions are then released to the system after checking if production of rails is going on. For the released transactions a check is made to determine whether hot-hour production is on or not.. If hot-hour production is off or structurals/suqares are being rolled, the GENERATEd transactions are at once TERMINATEd. If the Logic Switches 100 and 90 are in RESET and SET modes respectively, then the rails are being rolled. A test is then made for the availability of space at the cooling beds. Accordingly the transactions either leave QUEUE 1 without delay or join QUEUE 1 till space is available at cooling beds. These transactions after passing certain amount of time at cooling beds join QUEUE 2 where they wait for the availability of the FACILITY 1 (crane 1).

Parameters associated with each transaction have been used to define the flow of rail-bundles inside the model. For various policies for the movement

of the overhead cranes, separate programmes have been used. Indirect addressing is used to an advantage for writing a common programme for the movement of cranes from various origins to different destinations. Same series of blocks is used to advance the clock accordingly. In following paragraphs, the GPSS models for the various policies are presented.

POLICY A : The transactions waiting at the cooling beds in QUEUE 2 are serviced by crane 1 on a FIFO (first in first out) basis. A test is made whether the destination-pit (indicated by indirect address X*6) of this transaction is within the area allowed for crane 1 movement. Parameter P12 associated with such transactions is ASSIGNed a value equal to 100 showing that these rails belong to crane 1 region. Otherwise the parameter P12 is ASSIGNed a value equal to 200 showing crane 2 region. The present position of crane 1 (SAVEVALUE X111) is updated by moving the crane 1 to the calling cooling bed and then to the destination cooling pit after picking up the rails. If parameter P12 equals 200, then the SAVEVALUE X111 is put equal to X*8 (position of the platform) and the crane 1 drops the rails there. These rails join QUEUE 3 and wait for crane 2. When the crane 2 becomes free (not SEIZEd by any other transaction), it comes to the platform, picks up the rails and takes them to the destination-pit (X*6). GATE block has been

used to test the condition whether the pit is full or not. When a pit is full, the value of parameter P12 tells which crane is required to close the pit by cover. The same crane is required to open up the pit after $6\frac{1}{2}$ hours to $7\frac{1}{2}$ hours. After opening of the pit, the clock time is ADVANCEd by half an hour, on an average, during which the rails are left in the open pits.

For each transaction, the test report is generated and stored in parameter P10 to find whether the rails are acceptable or not. According to the past data, on an average, 90% of the rails are found to be acceptable. Same information has been utilized in this work to decide their destination. If the rails are found to be acceptable, they are destined for the transfer-beds. Otherwise, the transaction-parameter P7 is ASSIGNed a value to indicate the position where 10% rejected rails are to be unloaded.

In crane 1 area (parameter P12 = 100), if for a transaction, parameter P10 equals 0 i.e. the rejected rails, the present position of the crane 1 is updated by moving the crane to the calling pit. Clock time is accordingly ADVANCEd by movement time and loading time. Then the SAVEVALUE X111 is made equal to the position of platform (X*8) by moving the crane 1 to the platform where it drops the rails. These rails either SEIZE the crane 2 immediately (if free) or join the QUEUE 3.

Crane 2 takes these rails to the scrapyard-section given by parameter P7.

In crane 1 area (parameter P12 = 100), if for a transaction, parameter P10 equals 1(i.e. the accepted rails), the present position of crane 1 is updated by bringing the crane to the calling pit. The position of transfer-beds is compared with the platform location to decide which crane/s is essential for completing the move. If transfer-beds fall before the platform (X*8), crane 1 can take the rails to the transfer-beds. Otherwise crane 2 is also required to move the material from the platform to the transfer-beds. If crane 1 is not free at the time when the rails are ready to be served after cooling in the pits, the rails join QUEUE 5. As soon as the rails reach transfer-beds or scrapyard, the transaction is TERMINATEd i.e. the rails go out of the system.

Similarly in crane 2 area (parameter P12 = 200), if for a transaction, parameter P10 equals 3(i.e. rejected rails), that transaction is moved to scrapyard by means of crane 2. If parameter P10 equals 2 (i.e. accepted rails), the rails are destined for the transfer-bed. The position of transfer-beds is compared with the platform location. If transfer-beds lie within the range of crane 2, the rails are delivered to the transfer-beds by crane 2 only. Otherwise crane 2 drops the rails at platform and crane 1 is SEIZEd to deliver them to the

transfer-beds. A flow diagram for the GPSS model of this policy is given in Fig. 4. The transactions are TERMINATEd as soon as they reach transfer-beds or the scrapyard.

POLICY B : In the GPSS model for this policy, at any instant subroutines EWWE1 and EWWE2 find the directions of movement of crane 1 and crane 2 respectively. These directions are stored in SAVEVALUEs X113 and X213. In this model, both the cranes are allowed to move in the whole bay. NFREE is a subroutine which has been structured by using a number of TEST blocks, GATE blocks, logic Switches and arithmetic variables. The subroutine NFREE decides which crane is to be pre-empted and which one is to be moved at the time of conflict. During the simulation run, whenever the cranes move towards each other, this subroutine NFREE checks for the possibility of intercrane interference. When the difference between the present positions of both the cranes becomes equal to or less than 5.2 metres, the conflict occurs. NFREE then checks for the status of the cranes (free or loaded) and decides about the movement of cranes. A logical flow diagram for the GPSS model of this policy is given in Figures 5 and 6.

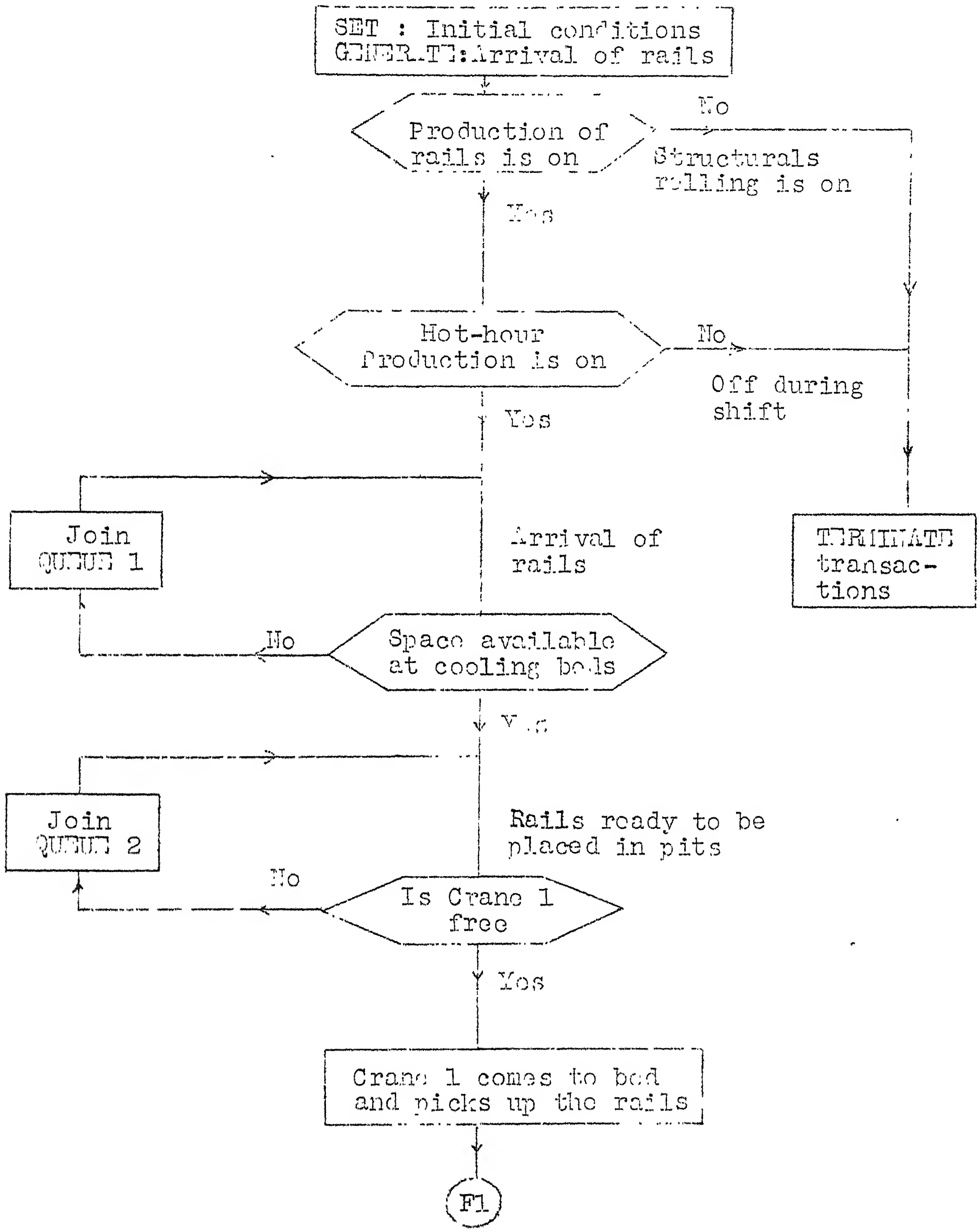


Figure 4 : Flow Diagram for Policy A

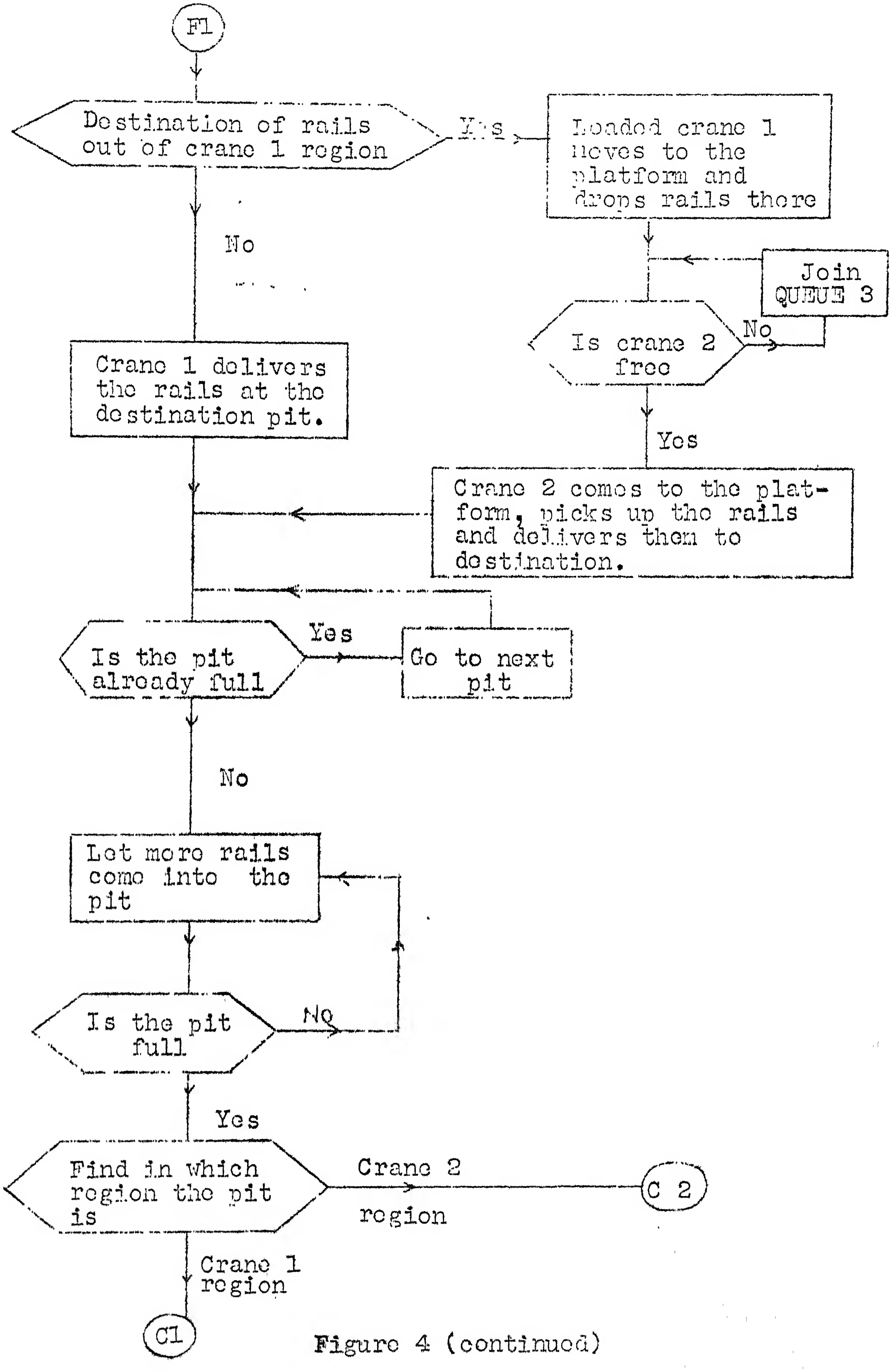
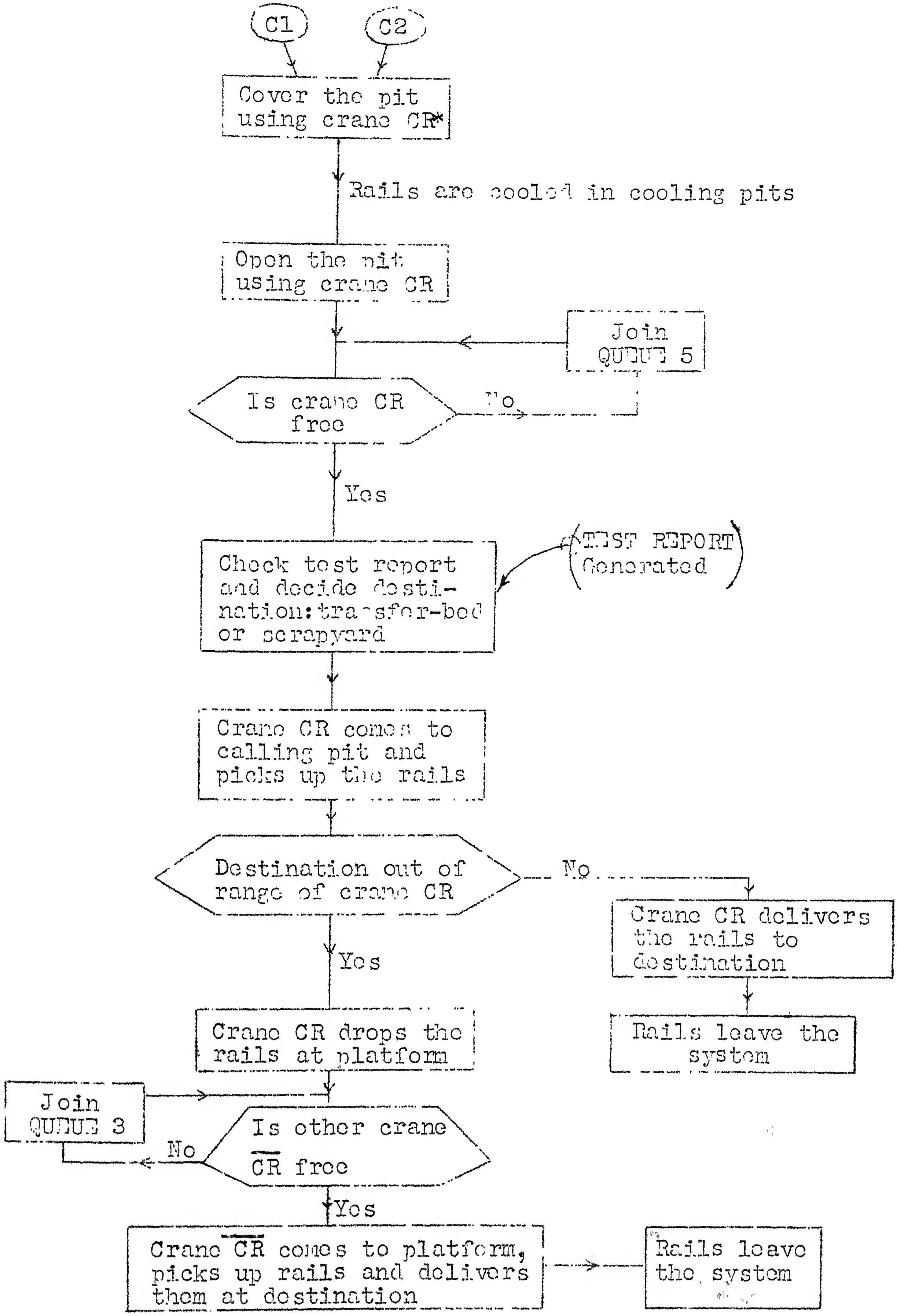


Figure 4 (continued)



NOTE: * CR-The crane selected

$\overline{CR}$-The other crane

Figure 4 (continued)

If one crane is free and other loaded (Logic Switches 111 and 211 are in opposite states - one SET, the other RESET) at the time of conflict, the free crane's present position is maintained and the loaded crane's present position is updated. However, to collect the statistics of PREEMPTed crane, the free crane is RELEASEd and a fictitious FACILITY is SEIZEd by the same transaction which is moved along with the loaded crane. This fictitious FACILITY is RELEASEd and the PREEMPTed crane is RETURNed to operation when the loaded crane moves past the interference position after delivering the load at the destination.

If both the Logic Switches 111 and 211 are at SET status at the time of conflict, this means that both the cranes are loaded. The programme finds out the distance of both the cranes from their respective destinations using indirect addressing of SAVEVALUEs. The crane nearer to its destination is moved and the other crane's movement is PREEMPTed. As mentioned above, to collect the statistics of the PREEMPTed crane, a fictitious FACILITY is SEIZEd. The operation of the fictitious FACILITY is the same as explained earlier.

The transactions are TERMINATEd as and when they reach either transfer-beds or scrapyard. TABULATE blocks have been inputted just before the TERMINATE blocks to give the statistics regarding the stay of the transactions in the system.

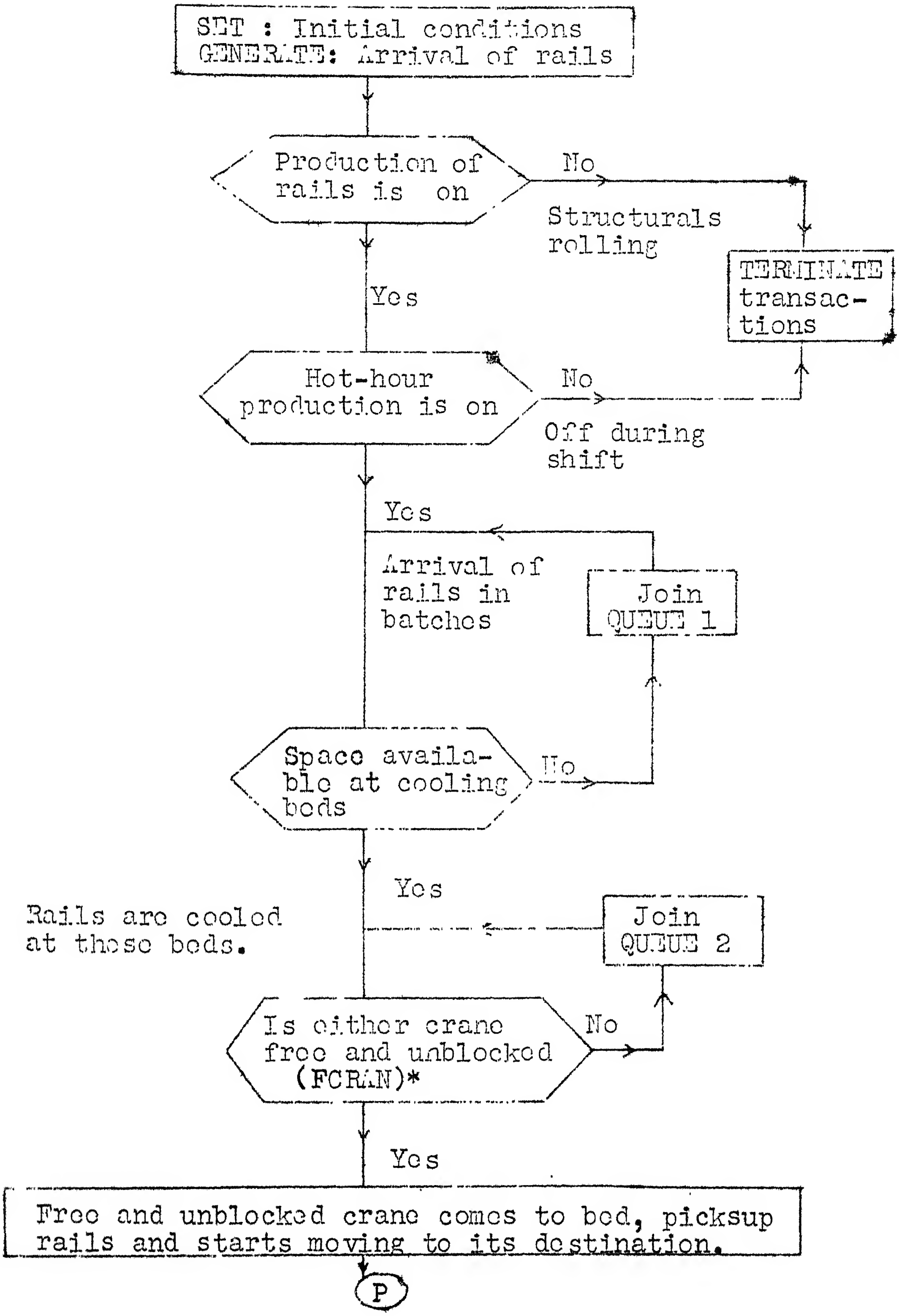
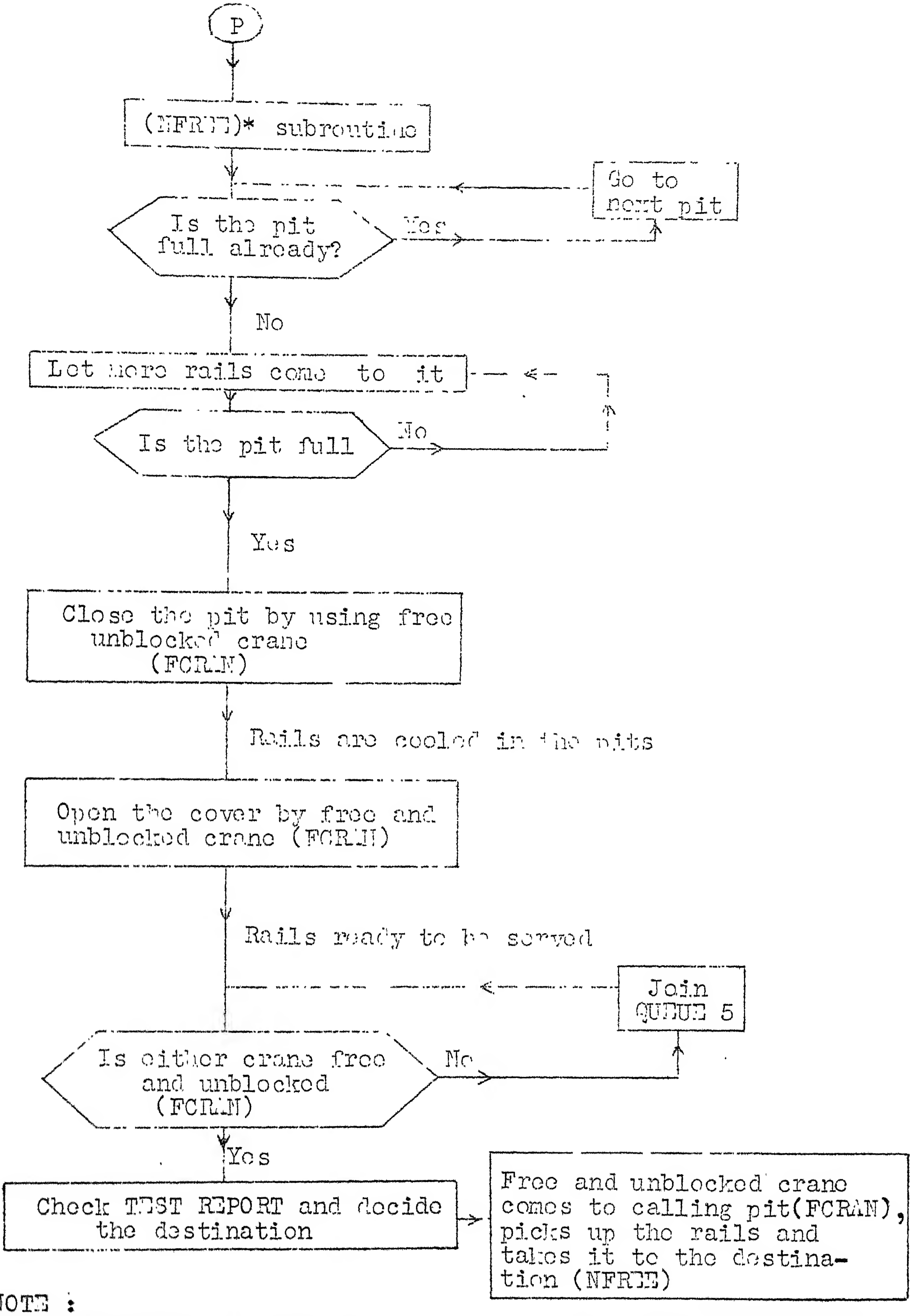


Figure 5 : Flow Diagram for Policies B and C



NOTE :
*Flow diagrams of subroutines called in are given separately.

Figure 5 (continued)

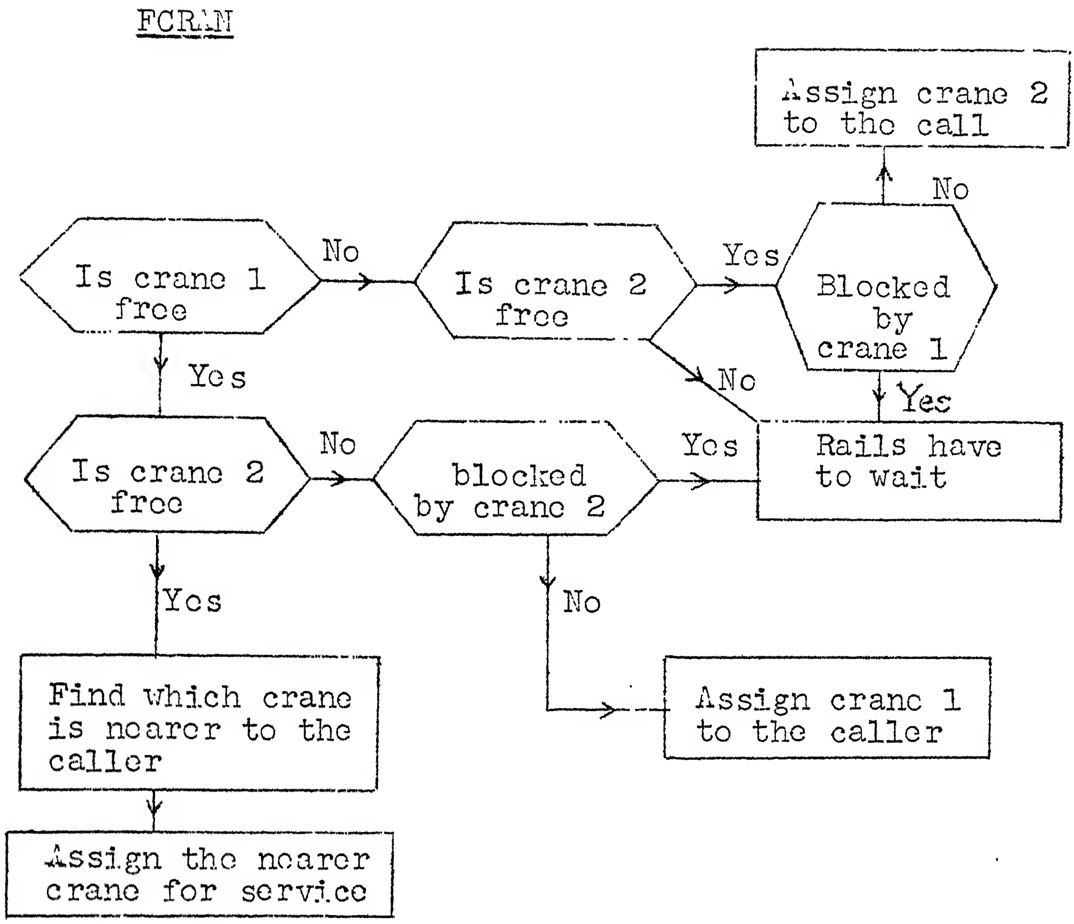


Figure 5 (continued)

NFREE

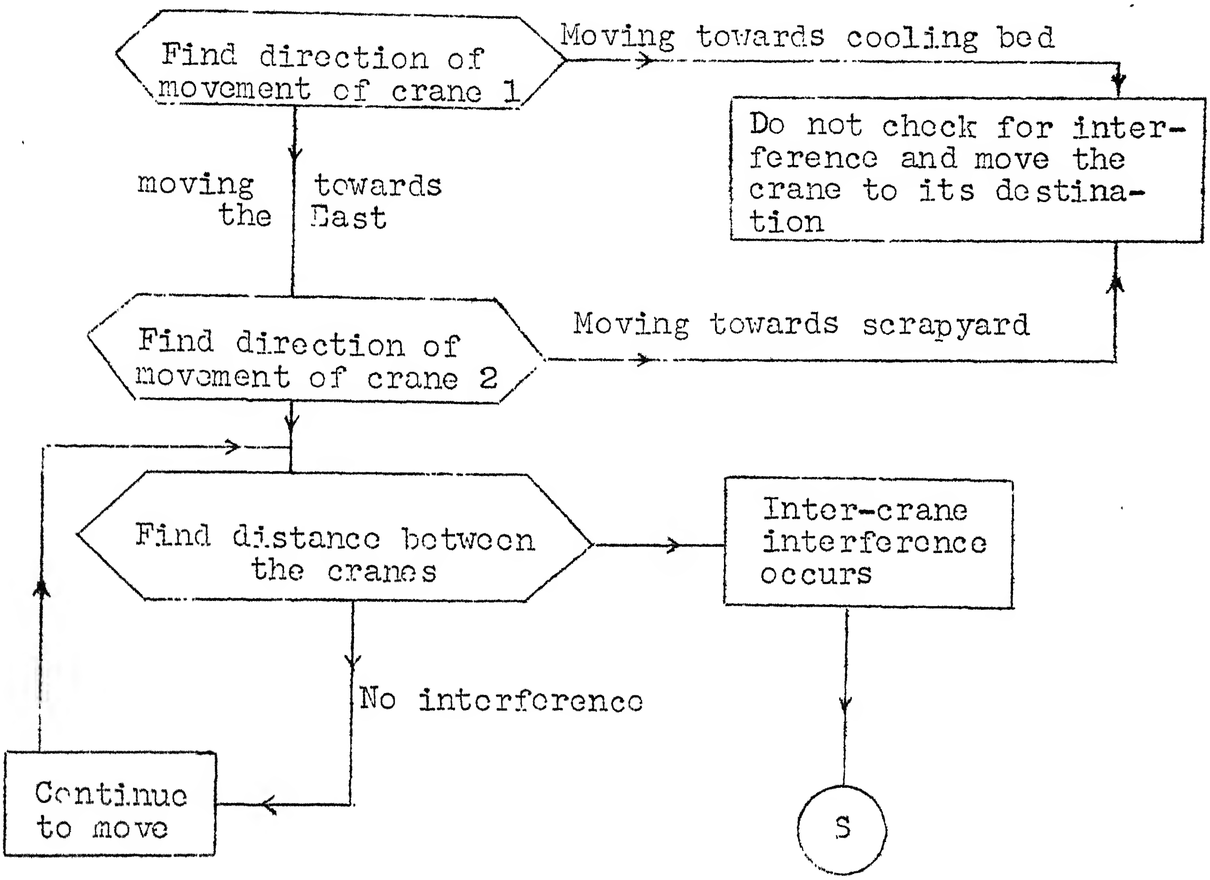


Figure 5 (continued)

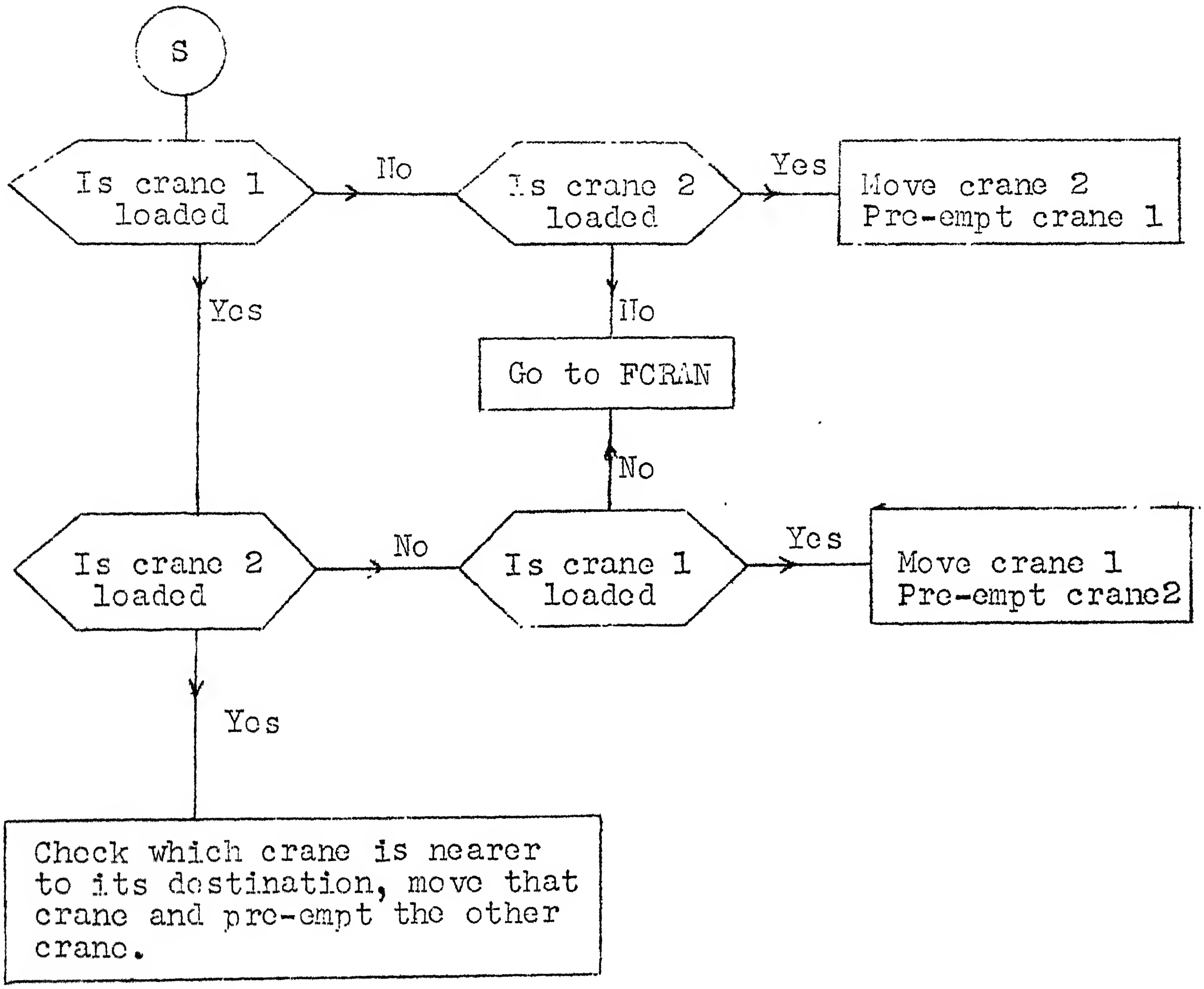


Figure 6 : Continuation of Figure 5 for Policy B

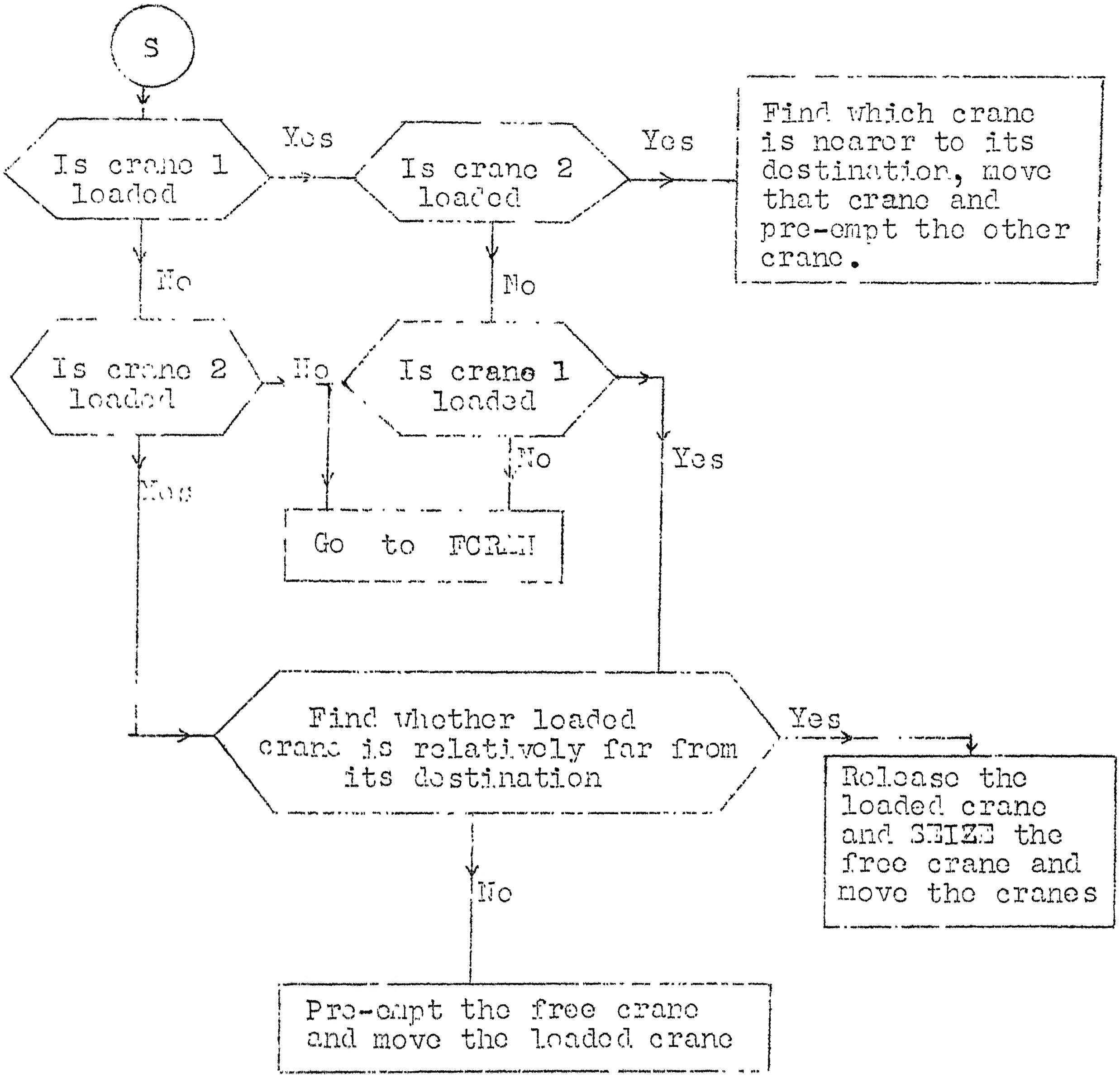


Figure 7 : Continuation of Figure 5 for Policy C.

If both the Logic Switches 111 and 211 are at SET status at the time of conflict, this means that both the cranes are loaded. The programme finds out the distance of both the cranes from their respective destinations using indirect addressing of SAVEVALUEs. The crane nearer to its destination is moved and the other crane's movement is PREEMPTed. As mentioned above, to collect the statistics of the PREEMPTed crane, a fictitious FACILITY is SEIZEd. The operation of the fictitious FACILITY is the same as explained earlier.

The transactions are TERMINATEd as and when they reach either transfer-beds or scrapyard. TABULATE blocks have been inputted just before the TERMINATE blocks to give the statistics regarding the stay of the transactions in the system.

POLICY C : The only difference in GPSS models of policy B and policy C is the change in the logic of subroutine NFREE which decides the way of using the cranes (one loaded, the other free) at the time of conflict. If one of the Logic Switches 111 and 211 is in SET status and the other one in RESET status, the steps mentioned in section 2.7 are carried out. These computations involve use of arithmetic variables and indirect addressing of destinations and present positions of the cranes. Depending upon the decision, either loaded crane drops the rails and free crane is SEIZEd

to take these rails to the destination or the free crane is PREEMPTed allowing the loaded crane to move. One fictitious FACILITY is introduced for each crane to collect the statistics of the PREEMPTed crane in same way as discussed previously.

If both the cranes are free and a call occurs for the crane, the subroutine FCRAN finds out which crane is nearer to the caller. The crane nearer to the caller is SEIZEd to entertain that call.

3.3 Design of Simulation Runs

When simulation is used as a tool to solve a problem, the answers are not unique. This is because in simulation, experiments are conducted using random numbers. The random numbers generated by the digital computers are not truly random in character. On the contrary they are pseudo-random numbers and depend on the initial value of the seed selected to start the generation of random numbers. In order to nullify the effect of the selection of initial value of the seed on the generated solution, it is necessary to have a number of simulation runs using different initial seed values.

Another very important decision in simulation studies is the decision regarding the length of the run. A low value for the duration of simulation run may give

very erroneous results. Though the accuracy of the results increases as the length of the simulation run increases but at the cost of high computational effort. In order to be in a position to have the desired accuracy in the results, it is necessary to statistically justify the selection of the duration of simulation run.

Also the successive simulation runs possess some degree of mutual correlation due to the fact that the starting conditions of each run are the finishing conditions of the previous run. This correlation can often be virtually eliminated by making use of natural periods present in the system being simulated.

The present system under study has the natural periods as the length of one rolling programme. After each rolling compaign of rails, there occurs rolling of structurals and/or squares. During this time both the cranes keep operating thereby clearing all the rails queued up in various QUEUEs by the time next rolling compaign of rails starts. Thus, the initial conditions for the successive period are same as the initial conditions of this period. The correlation between two successive runs has been eliminated by making use of these natural periods which are present in the system being simulated. It is, therefore,

reasonable to consider that the total length of simulation job can be broken up into a set of runs, the results from which can be taken as independent values sampled from some unknown parent population.

The choice of a satisfactory number of runs to be simulated is based on statistical methods of sample size estimation. The procedure for the determination of this number is discussed in following paragraphs. For complete details of the procedure, the reader may refer to the reference [4].

(i) Considering the tolerable sampling error, a confidence coefficient C is specified for the results to be in confidence interval I. The relationship between C and I is as follows (refer Figure 8).

$$\text{prob.}\left[\overline{U} - I \leqslant \overline{\overline{U}} \leqslant \overline{U} + I\right] = C$$

where, $\overline{U}$ is sample mean

and $\overline{\overline{U}}$ is the mean of sample means and is an estimator of population mean.

(ii) N number of runs are taken and the values of utilization (one from each run) are noted down.

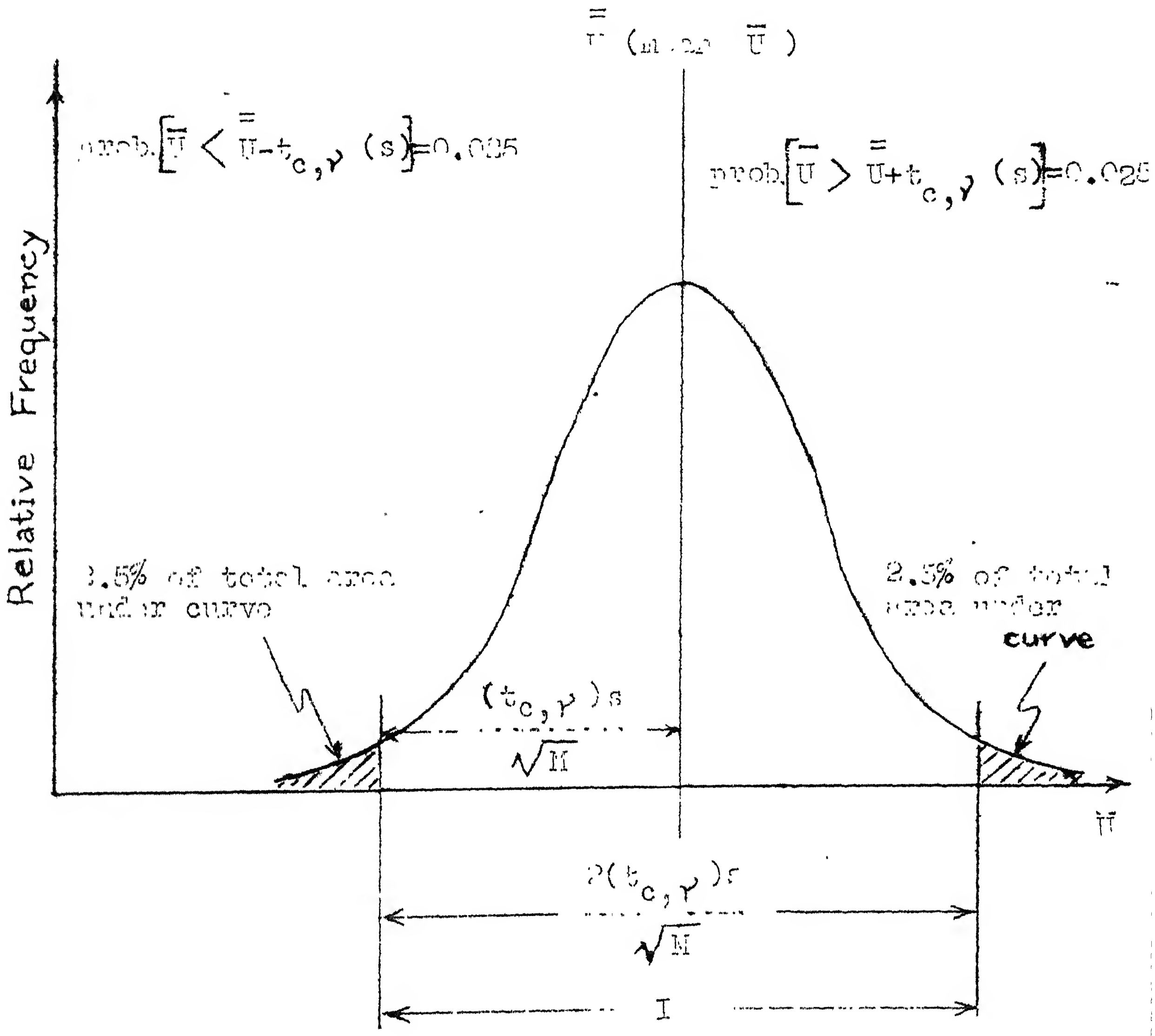


Figure 8 : t-Distribution of Sample Means

(iii) Sample standard deviation 's' is calculated from the following formula :

$$s = \sqrt{\frac{\bar{\bar{U}}^2 - \frac{(\sum \bar{U})^2}{M}}{M-1}}$$

(iv) The number of runs N required is calculated using the following relationships :

$$N = \frac{4 \times t_{c,\gamma} \times s^2}{I^2}$$

where $t_{c,\gamma}$ is the t-value from student's t-distribution for confidence level of C and γ degrees of freedom. Here γ is equal to M-1.

(v) If $N > M$, then N-M more simulation runs are taken, otherwise M runs already taken are adequate.

In the present simulation study, the number of runs M has been chosen as 8. To have 95% confidence in the average utilization values to be in a confidence interval of .02 (± .01), actual number of runs N required is calculated as below :

$$M = 8$$

$$\gamma = M-1 = 8-1 = 7$$

$$t_{c,\gamma}^{*} = t_{95,7} = 2.36$$

$$\bar{\bar{U}} = 0.8627 = \frac{\sum_{i=1}^{8} \bar{U}_i}{8}$$

$$s = 0.001355$$

---

* t-values from student's t-distribution for certain values of γ and C are given in Appendix E.

$$\therefore \quad N = \frac{4 \times (2.36)^2 \times (.001355)^2}{(.02)^2}$$

$$= 10.2 \simeq 11$$

$$N-M = 11-8 = 3$$

Therefore, 3 more runs have been taken. Mean values have been calculated from these 11 values of average utilization of cranes. For a 95% confidence, it can be said that the population mean would lie within $\pm$ .01 interval from the value estimated with the help of 11 simulation runs.

3.4 Comments on Simulation Using GPSS III

The prime consideration for the development of a simulation model is to restrict the size of the model so that the memory requirements are not greater than the memory available on the computer. Therefore, it is always better not to start with too many details. Rather, the details should be added later as the problem becomes better defined. On the IBM 7044 system, the memory available for GPSS III is 18.65K. Moreover, in GPSS III, at the most 750 transactions can be handled at a time. The size of the present system under study is such that if one piece of rail is represented by a transaction in the model, this limit of 750 transactions is exceeded. Therefore, it was necessary to scale down the model by representing 10 rails by 1 transaction.

This scaling factor of 10 has been selected because the overhead cranes have a capacity to handle a maximum of 10 rails. Even after the scaling down, ERROR NR 68 was occuring which read TRANSACTION SPACE EXCEEDED. To avoid this ERROR, only those transactions are kept alive which are essential.

While developing the model, a very peculiar error was encountered. The error read.

ERROR NR 0 23575

TRANS...A...B ...C...CLOCK...TERMINATIONS TO GO...

This error number is not listed even in the GPSS III User's Manual [2] of IBM. An attempt was made to interpret this error but so far it is not possible to putforth any conclusive explanation.

During the development of the simulation model, the following approaches were used to debug the model.

(i) The simulation run is frozen at a particular prefixed time to determine why a particular transaction is where it is?

(ii) Each class of item is followed through the logic of the model. This is achieved by using TRACE and UNTRACE blocks.

(iii) The sequence of all the blocks that produce an action is stored. This helps in providing a catalog of actions in the model. These actions

are grouped according to their type. For various actions, the parameters are directly ASSIGNed different values. This technique is of considerable utility because it helps in keeping a concise record of the complex and lengthy model.

CHAPTER IV

RESULTS AND DISCUSSIONS

At the completion of each simulation run, various statistical reports are printed. These reports indicate the model's reaction to the material handling policies and the selected values for the storage locations, the speed of cranes and other parameters. These reports contain information about the QUEUE lengths, maximum contents of QUEUEs, FACILITY utilization, average handling time and other pertinent statistics.

The effects of various parameters and material handling policies on the utilization of cranes are given in Tables I through VIII. In the following paragraphs the results are analysed and discussed to determine the best policy for using the cranes and the best layout of facilities.

4.1 Effect of Policy A on Crane Utilization

Table I shows the utilization of the cranes and the maximum contents of QUEUEs for Policy A. The results tabulated in this table are based on a crane speed of 2.6 metres/second for both the cranes and a cooling time of 1320 seconds at the cooling beds. The utilization of crane 1 is of the order of 80% while the lowest value of the utilization of crane 2 is 27%.

[illegible] L
[illegible]
([illegible])

POLICY A
MEAN COOLING T[illegible]
AVERAGE SP[illegible] = [illegible]
AV. RIG. SP[illegible] = [illegible]
CLOCK TIME [illegible]
AV. UT. [illegible]

([illegible]) POSITION [illegible]
POSITION [illegible]

POSITION OF PLATFORM IN MM.		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	54 [illegible]	[illegible]	[illegible]	[illegible]
9[illegible]	CLOCK TIME	[illegible]	[illegible]	[illegible]	[illegible]	
		AV. UT.	AV. UT.	AV. UT.	AV. [illegible]	[illegible]
	CRANE [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	CRANE [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]7540	CLOCK TIME	[illegible]	[illegible]	[illegible]	[illegible]	
		AV. UT.	AV. UT.	AV. UT.	AV. [illegible]	[illegible]
	CRANE [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	CRANE [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]5900	CLOCK TIME	[illegible]	[illegible]	[illegible]	[illegible]	
		AV. UT.	AV. UT.	AV. UT.	AV. UT.	[illegible]
	CRANE [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	CRANE [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]4390	CLOCK TIME	[illegible]	[illegible]	[illegible]	[illegible]	
		AV. UT.	AV. UT.	AV. UT.	AV. UT.	[illegible]
	CRANE 1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	CRANE 2	[illegible]	.47[illegible]	[illegible]	[illegible]	[illegible]
12660[illegible]	CLOCK TIME	[illegible]	[illegible]	[illegible]	[illegible]	
		AV. UT.	AV. UT.	AV. UT.	AV. UT.	[illegible]
	CRANE [illegible]	[illegible]	.87[illegible]	[illegible]	[illegible]	[illegible]
	CRANE [illegible]	.72[illegible]	.76[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

(A) POSITION OF TRA SFOR-I [illegible] IS 7[illegible] [illegible]
POSITION OF TR. SF R-[illegible] 9 [illegible]

POSITION OF PLATFORM IN MMS.		OUTPUT OF THE [illegible]		[illegible]		[illegible]
		[illegible]	5[illegible]	[illegible]	[illegible]	
	CLOCK TIM	[illegible]	[illegible]			
76[illegible]		V. UT.	AV. U[illegible].	V. [illegible].	V. [illegible].	[illegible]
	C[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	
	C[illegible]	.[illegible]	.[illegible]	[illegible]	.[illegible]	[illegible]
	CLOCK TIM	[illegible]54	[illegible]	[illegible]	[illegible]	
.59[illegible]		AV. UT.	AV. U[illegible].	V. U[illegible].	V. [illegible].	[illegible]
	C[illegible]	.[illegible]	.[illegible]9	.[illegible]	.[illegible]	[illegible]
	C[illegible]	.44[illegible]	.[illegible]	[illegible]	.[illegible]	[illegible]
	CLOCK TIM	[illegible]264	[illegible]	[illegible]		
.4090		V. UT.	AV. U[illegible].	V. [illegible].	V. [illegible].	[illegible]
	C[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	[illegible]
	CR[illegible]	.[illegible]94	.[illegible]	.[illegible]	.[illegible]	[illegible]
	CLOCK TIM	[illegible]	2[illegible]9	[illegible]	[illegible]	
.2660		AV. UT.	AV. U[illegible].	AV. U[illegible].	AV. [illegible].	[illegible]
	CR[illegible]	.3[illegible]	.[illegible]	.[illegible]	.[illegible]	[illegible]
	CR[illegible]	.[illegible]94	.4[illegible]	.[illegible]9	.[illegible]	[illegible]

[illegible]

(A[illegible]) POSITION [illegible]
POSI[illegible] OF [illegible]

POSITION OF PLATFORM IN MM.		TOTAL [illegible]				[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	CLOCK [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		AV. UT.	AV. UT.	[illegible]	[illegible]	[illegible]
	C[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	C[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
439[illegible]	CLOCK [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	AV. [illegible]	[illegible]	[illegible]	[illegible]
	C[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	C[illegible]	.5[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]66[illegible]	CLOCK [illegible]	[illegible]	[illegible]	[illegible]		[illegible]
		AV. UT.	AV. [illegible]	[illegible]	[illegible]	[illegible]
	CR[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	C[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Considering 5280 rails leaving the system, the highest value of the simulated clock time is 167892 seconds.

For the selected length of simulation run, the percentage utilization of cranes improves as the simulation progresses in time but its value goes down between the production of rails termination and restart. The decrease in the percentage utilization during the termination and the restart of the production of rails occurs due to the fact that for sometime during this period the cranes are idle.

4.2 Effect of Policies B and C on Cranes Utilization

The results of Policies B and C are tabulated in Tables II and III. In these policies the average utilization of the cranes is found to be about 25% resulting in an uneconomical use of the cranes. There are two possible reasons for the low utilization of the cranes in these policies. Either the crane remains idle for quite some time due to the non-availability of the rails or the cranes pass a considerable period of time when blocked. In case the cranes are blocked, the rails which are moved by equipments other than the cranes get queued up. Also as the time elapses, the rails after completion of cooling time at various beds, pits join the QUEUEs. These QUEUEs, in turn, fill up the place required for the storage of rails and thus the rails cannot be transferred to these storages.

[illegible]

([illegible] IN L [illegible])

[illegible] = [illegible]
= [illegible]
= [illegible]

		[illegible] OF THE SYSTEM		PRODUCTION OF [illegible]		[illegible] CONT OF
		[illegible]	F [illegible]	T [illegible]	P START [illegible]	
	[illegible]		[illegible]	[illegible]	[illegible]	[illegible] =
	[illegible] Y [illegible] Y	AV. UT. . [illegible] . [illegible] . [illegible] . [illegible]	AV. UT. . [illegible] . [illegible] . [illegible] . [illegible]	AV. UT. . [illegible] . [illegible] . [illegible] . [illegible]	AV. UT. . [illegible] . [illegible] . [illegible] . [illegible]	[illegible] = Q[illegible] =
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] =
	[illegible] Y [illegible] Y	AV. UT. . [illegible] . [illegible] . [illegible] . [illegible]	AV. UT. . [illegible] . [illegible]96 . [illegible] . [illegible]	AV. UT. . [illegible] . [illegible] . [illegible] . 79	AV. UT. . [illegible] . [illegible] . [illegible] .	Q[illegible] = Q[illegible] =
	[illegible]	[illegible]	[illegible]	[illegible]76.25	[illegible]	Q[illegible] =
	[illegible] Y [illegible] Y	AV. UT. . [illegible] . [illegible] . [illegible] . [illegible]	AV. UT. . [illegible] . [illegible] . [illegible] . [illegible]	AV. UT. . [illegible] . [illegible] . [illegible] . [illegible]3	AV. UT. . [illegible] . [illegible] . [illegible] . [illegible]	Q[illegible] = Q3 =

TABLE [illegible]

[illegible]

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		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Q = [illegible]
	[illegible]	AV. UT.	AV. UT.	AV. UT.	AV. UT.	Q = [illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Q5= [illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Q = [illegible]
[illegible]	[illegible]	AV. UT.	AV. UT.	AV. UT.	AV. UT.	Q = [illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Q5= [illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Q = [illegible]
[illegible]	[illegible]	AV. UT.	AV. UT.	AV. UT.	AV. UT.	Q = [illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Q5= [illegible]

The Tables II and III depict that the maximum contents in the QUEUE 5 after cooling of rails in the pits is of the order of 2300. This indicates that these many rails keep on occupying the pits till they are taken out by the cranes. Therefore, the rails from the cooling beds also cannot be transferred to these pits as overloading of pits is not allowed. The material handling rate is calculated by noting the simulated clock time taken for the handling of 5280 rails. The minimum value of the clock time observed in Policies B and C are 175806 seconds and 174086 seconds respectively.

As per the current practice, QUEUE 5 is maintained in the scrapyard and even the rails which are acceptable are taken to the scrapyard. The acceptable rails are brought from scrapyard to the transfer-beds when cranes have time to handle these rails. This handling of rails accounts for an unnecessary usage of the cranes. This is probably the reason for the cranes to be busy for most of the time under the present policy for using the cranes. The same reasoning can be given for low utilization of the cranes in Policy C because Policy C is quite identical to the present policy.

4.3 Comparison of Cranes Utilization Under Various Policies

The overall utilization of cranes is higher for Policy A than Policies B and C. The rate of handling

rails is higher for Policy A in comparison to Policies B and C.

In comparison to Policy B, the Policy C a higher rate for the handling of rails. Utiliz of the cranes is more for Policy C as compared t Policy B. The inter-crane interference is found less in Policy C. This means that for most of t times, the interference occurs between a loaded and an unloaded crane. Moreover, in Policy C, tl transference of load from the loaded crane to th unloaded crane is permitted if the loaded crane relatively far away from its destination (refer 2.7.3).

4.4 Effect of Shifting the Transfer-Beds on the Under Various Policies

The following inferences are drawn from results presented in Table I for Policy A. The refer to the situation when the position of tran beds is shifted towards the West.

(i) The utilization of both the cranes decrease

(ii) The rate of handling rails increases.

(iii) The maximum contents in QUEUE 2 (results fr cooling at the cooling beds) increases.

(iv) The maximum contents in QUEUE 3 (at the pla decreases.

rails is higher for Policy A in comparison to Policies B and C.

In comparison to Policy B, the Policy C gives a higher rate for the handling of rails. Utilization of the cranes is more for Policy C as compared to Policy B. The inter-crane interference is found to be less in Policy C. This means that for most of the times, the interference occurs between a loaded crane and an unloaded crane. Moreover, in Policy C, the transference of load from the loaded crane to the unloaded crane is permitted if the loaded crane is relatively far away from its destination (refer section 2.7.3).

4.4 Effect of Shifting the Transfer-Beds on the System Under Various Policies

The following inferences are drawn from the results presented in Table I for Policy A. The results refer to the situation when the position of transfer-beds is shifted towards the West.

(i) The utilization of both the cranes decreases.

(ii) The rate of handling rails increases.

(iii) The maximum contents in QUEUE 2 (results from the cooling at the cooling beds) increases.

(iv) The maximum contents in QUEUE 3 (at the platform) decreases.

(v) The maximum contents in QUEUE 5 (after cooling in the pits) increases.

In Policy B, no appreciable change in the average utilization of the cranes is found with the shift in the transfer-beds. However, the inter-crane interference increases as the transfer-beds are shifted towards the West. A decrease in the value of maximum contents in QUEUE 2 is observed while maximum contents in QUEUE 5 remains somewhat constant as the location of the transfer-beds is shifted towards the West.

In Policy C, as the transfer-beds are shifted towards the West, the rate of handling rails decreases and the utilization of both the cranes also decreases. It is not possible to draw any conclusive inferences regarding the behaviour of QUEUE contents.

Considering the effective utilization of the cranes and the rate of handling the rails, Policy A is better than Policies B and C. The drawback with the Policy A is that the maximum contents of QUEUE 2 is very large. To keep the various queues in limit, various experiments have been performed on this policy. The results of these experiments are discussed in the following sections.

4.5 Effect of Shifting the Platform in Policy A

When the transfer-beds are located at 190,000mm. and 206,000 mm. from the western edge of first cooling bed (refer Appendix A) and the position of the platform is shifted in steps of one pit length from 190,000 mm. to 126,000 mm. (Table I), the following results are obtained :

(a) Following are the inferences on maximum queue contents noted for a period of one rolling programme -

i) The maximum contents of QUEUE 2 decreases from 2830 rails to 530 rails.

ii) The maximum contents of QUEUE 3 increases from 10 rails to 620 rails.

iii) There is an increase in maximum contents of QUEUE 5 also from 120 rails to 480 rails.

(b) The inferences on utilization of the cranes for handling an output of 5280 rails are as follows -

i) The average utilization of crane 1 decreases slightly from .8959 to .8452.

ii) The average utilization of crane 2 increases from .2696 to .7201.

iii) The rate of handling of the rails becomes faster. This is indicated by a decrease in the clock time from 167892 seconds to 127252 seconds.

Similar inferences result from the experiments conducted by locating the transfer-beds at different positions and shifting the platform in steps of one pit length for each experiment. For a fixed position of transfer-beds, as the platform is shifted towards the West, the area for movement of crane 1 reduces while the area for movement of crane 2 increases. More and more number of rails having their destination in crane 2 region engage both the cranes for their transfer from the cooling beds to the cooling pits by making use of the platform in-between.

4.6 Effect of Speed of Cranes in Policy A

The results obtained by varying the speed of the cranes as well as the position of the platform for the existing positions of the transfer-beds (190,000 mm. and 206,000 mm.) are given in Tables IV through VIII. The location of the platform is varied in steps of one pit length. For each location of the platform, the speed of the cranes is varied in steps of 0.1 metres/second from 2.6 metres/second to 3.0 metres/second. These alternative speeds of the cranes have been experimented with an idea of controlling the out of limit QUEUE contents.

The following effects are observed when the speed of crane 2 is kept constant at 2.6 metres/second

[illegible] L [illegible] V

[illegible] FOR POLICY [illegible]

[illegible]

[illegible] FROM FIRST CYCLING [illegible] C.

[illegible] FROM TH[illegible] FIRST CYCLING [illegible]

		[illegible] SYS[illegible]		[illegible] ION OF [illegible] ILL		[illegible] IMUM CONT [illegible] OF
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		AV. UT. [illegible]	AV. UT. .[illegible]7[illegible] .[illegible]56	AV. UT. .[illegible]99[illegible] .[illegible]96	AV. UT. .7[illegible]	Q = [illegible] Q2 = 35[illegible] Q3 = [illegible] Q5 = [illegible]

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		[illegible]	.[illegible]	.9[illegible]	.[illegible]	Q = [illegible]
		[illegible]	.[illegible]	.[illegible]	.[illegible]	Q5= [illegible]
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T[illegible]L[illegible] V[illegible]

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COOLING TIM[illegible] OOLING [illegible]S = [illegible]

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[illegible]C OF C[illegible]		OUTPUT OF TH[illegible] CY[illegible]		[illegible]		[illegible]
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	CR[illegible]	.7 9[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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	CLOCK TIM[illegible]	[illegible]	[illegible]	[illegible]		
9		[illegible]V. [illegible]T.	AV. [illegible]	V. [illegible]	[illegible]V. [illegible]	[illegible]
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and the speed of crane 1 is increased from 2.6 metres/ second to 3.0 metres/second with the platform located at 190,000 mm. (refer Table IV).

(a) Following are the inferences on maximum queue contents observed over a period of one rolling programme -

i) The maximum contents of QUEUE 2 decreases from 3920 rails to 30 rails.

ii) The maximum contents of QUEUE 3 increases from 10 rails to 420 rails.

iii) The maximum contents of QUEUE 5 also increases from 240 rails to 600 rails.

(b) The inferences on utilization of cranes for handling an output of 5280 rails are as follows -

i) The utilization of crane 1 reduces from .8959 to .8675.

ii) The utilization of crane 2 increases from .2696 to .3309.

iii) The rate of handling of the rails becomes faster as indicated by a decrease in clock time from 167892 seconds to 141783 seconds.

The following inferences are drawn from the results obtained when the speed of crane 1 is kept constant and the speed of crane 2 is increased in steps of 0.1 metres/second from 2.6 metres/second to 3.0 metres/ second. The results are given in Table IV.

(a) The inferences on maximum queue contents observed over one rolling programme are given below -

i) The maximum contents of QUEUE 2 increases slightly from 30 rails to 40 rails.

ii) The maximum contents of QUEUE 3 reduces from 420 rails to 10 rails.

iii) The maximum contents of QUEUE 5 reduces from 600 rails to 240 rails.

(b) Following are the inferences on utilization of the cranes for handling an output of 5280 rails -

i) The utilization of crane 1 reduces from .8675 to .8562.

ii) The utilization of crane 2 increases from .3309 to .3236.

iii) The rate of handling of the rails increases as shown by a decrease in clock time from 141783 seconds to 139006 seconds.

A look into the tables from V to VIII indicates that similar inferences on the utilization of cranes and various queue contents result when the platform location is changed.

For all the cases, it is inferred that for a constant speed of crane 2, the utilization of crane 1 decreases as the speed of crane 1 is increased. However, the decrease in the utilization of crane 1 is far less

than the increase in the utilization of crane 2. Further, an increase in maximum contents of QUEUE 3 and QUEUE 5 is observed while the maximum contents of QUEUE 2 decreases.

When the speed of crane 2 is increased keeping the speed of crane 1 fixed, it is found that the utilization of both the cranes decreases. It is observed that the maximum contents of QUEUE 2 increases while the maximum contents of QUEUE 3 and QUEUE 5 decreases. The rate of handling of the rails goes on improving as the speed of either one of the cranes is increased.

4.7 Concluding Remarks

For an output of 5280 rails, at present the cranes are busy in handling these rails for about 45 hours. The results based on this study indicate that for the same output the cranes need to be busy only for about 39 hours if following recommendations are implemented:

(a) The cranes should be operated according to Policy A in order to achieve higher utilization of both the cranes and a faster rate of handling of the rails.

(b) The platform introduced should be between the transfer-bed and the cooling pit numbered 38 (refer Appendix A), i.e. at a distance of 190,000 mm. from the western edge of the first cooling bed.

(c) The speed of both the cranes should be increased to 3.0 metres/second i.e. 180 metres/minute. This 16% increase in the speed of both the cranes ensures the maximum contents of the queues to be within the specified limits. The present layout of the Rail and Structural Mill restricts the size of the queue for the rails to 10 for QUEUE 1, 90 for QUEUE 2 and 600 for QUEUE 5. The platform introduced is assumed to have a capacity for 20 rails only.

There would be a saving of 6 hours for rolling 5280 rails if the above mentioned suggestions are implemented. This saving will be much more when the full rolling programme is considered and still more if the production of rails is considered over a period of one year.

Had the system been designed from scratch, there would have been a lot of flexibility in the selection of design variables and this might have resulted in still better utilization of the cranes and higher rate for handling of the rails.

Due to the existence of a running system, no change in the layout has been suggested as there would be a very high cost associated with the disruption of layout. The time taken to instal any modification is important because during that time the production of rails will have to be completely shut down.

CHAPTER V

IMPLEMENTATION OF THE RESULTS AND SCOPE FOR FURTHER RESEARCH

5.1 Acceptance and Implementation of the Results

From the system designer's viewpoint, nothing is ever perfect. Simulation, like any new technique, can be expected to have drawbacks. The major difficulty with the use of simulation is to get the customer to have confidence in the simulation. This means confidence in the model, the data, the rules and the results. In case, the customer does not develop the model himself, then the modeler may find it difficult to comprehend and state the problem explicitly. For a simulation study to be a success, it is necessary that both the groups - one problem oriented and the other simulation oriented - must collaborate.

In order to have better acceptance and implementability of the results of a study, the customer has to be satisfied throughout the system design process. The model should very well document the problem and should be checked by the customer during its development. This procedure will give a better feel to the customer also what is going on. More important, it will provide feedback to the modeler that the problem being modelled is the problem that should be solved. The difficulties

increase when the customer leaves the model and the modeler alone for long periods. List of assumptions should also be stated, reviewed with the customer and then should be updated accordingly. The interim results must be discussed with the customer to re-estimate the model's veracity and pertinence of its abstractions. The customer can make a meaningful contribution when the model is still fluid, before the design specifications are firm.

The customer can more readily accept the results from the simulation when he has been a part of its development and has been asked to interpret the results rather than approve some final results.

For the present work, it has not been possible for the author to keep the customer (the management of Bhilai Steel Plant) aware of the progress of simulation results from time to time. This happened primarily because the author is at Kanpur and the customer is at Bhilai. Only the final results suggesting a policy for using the cranes for an improvement in their utility are being sent to the management of Bhilai Steel Plant for approval.

5.2 Numerically Controlled Rails Handling

The author thinks that the movements of both the cranes can be controlled and automized using a computer having the developed GPSS package. The conceptualized numerically controlled rails handling system would work in the following fashion.

The layout of the mill, various stopping positions of the cranes, arrival time of rails at the transfer-beds, the cooling time required at various service stations, the maximum contents allowed in various queues and the speeds of the crane-bridges as well as of the cabs and hooks are given as the inputs to the computer. Various priority rules can be specified before the system is put into operation.

One can use photoelectric cells to count the rails at various stations. The computer would maintain a list of rails waiting for service in different queues along with the destination of these rails. According to the priority rules and service discipline the rails movement would be materialized and controlled using the computer. At various check-points, a warning bell would indicate if the queue goes beyond a prespecified value of the maximum contents in that queue.

The thermostats can be used to actuate the sensing switches to bring about the required move if the temperature of rails goes below a certain point. The

loading and unloading of the cranes can be controlled using some electrical circuits actuated by the contact of magnetic hook and the rails. In this hypothetical system, the pit covers would be of the sliding type as are used in the case of soaking-pits. This would avoid unnecessarily engaging the cranes for closing and opening of the pits.

It is envisaged that the numerically controlled handling of the rails would improve the productivity of the mill.

5.3 Scope for Further Research

For this study, it is assumed that the system is independent of its environment. In reality the various components of the system interact with the environment and also inter-react. Therefore, it would be desirable to study the overall production system of Bhilai Steel Plant with Rail and Structural Mill as one of the components of the system.

In the present work, the hot-hour production is taken to be 5 to 7 hours during a shift. The actual frequency of the non-rolling time during a shift needs to be studied. This information can be inputted to the developed GPSS model as a function controlling the production of rails. It would be worthwhile to study the reaction of this function on the model.

The model can very easily be modified for three or four cranes working on the same tracks. For an increase in the production of rails in future, the same model can be used to decide the number of cooling beds, cooling pits, and cranes. The various capacities of these facilities, the speeds of the cranes and other pertinent information can be obtained from the same model with very little modifications.

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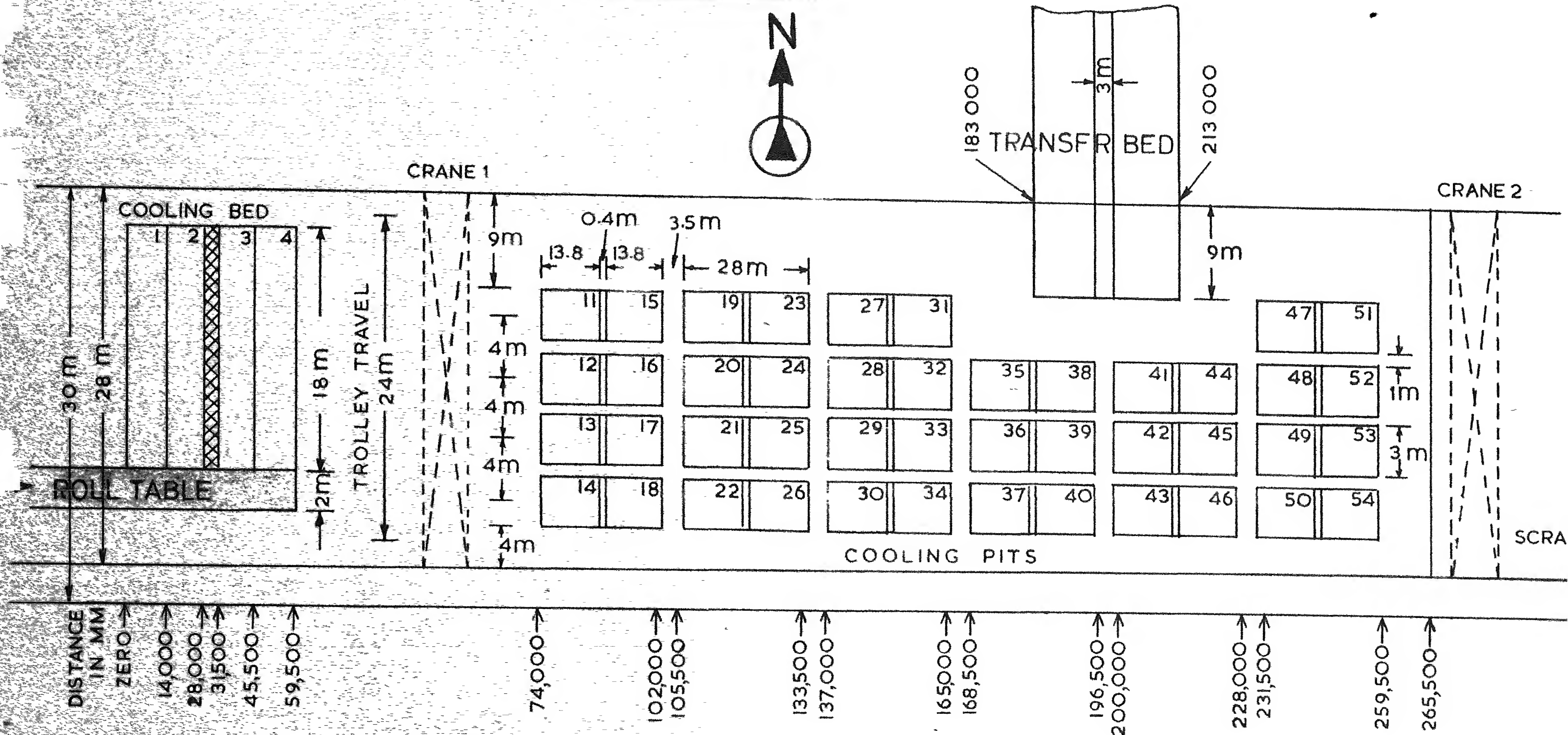
APPENDIX - A



BAY B-C OF RAIL & STRUCTURAL MILL OF BHILAI STEEL PLANT

(Not to scale)